No. 210. Vol. XXXV. JUNE, 1888.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

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THIRD SERIES.

VOL. XXXV.—[WHOLE NUMBER, CXXXV.]

No. 210—JUNE, 1888.

WITH PLATES VI AND VII.

NEW HAVEN CONN.: J. D. & E. S. DANA.
1888.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXXVI.—*Note on Earthquake-Intensity in San Francisco;* by EDWARD S. HOLDEN, LL.D., Director of the Lick Observatory.

TOWARD the end of 1887, the Regents of the University of California published a pamphlet prepared by me bearing the title "List of Recorded Earthquakes in California, etc.;" 1887; 8vo, pp. 78. This work contained all the information regarding California earthquakes which I have been able to collect. The information is presented in a popular rather than a scientific form, though the Introduction contains statistics, more or less valuable, relating to the distribution of the shocks by years, months and seasons.

It is the object of the present note to obtain an estimate of the absolute value of the earthquake-intensity developed at San Francisco during our historic period. I am obliged to confine myself to San Francisco, whose records are very complete, owing to the conscientious care of Mr. Thomas Tennant.

With this end in view I have gone over the printed pamphlet and wherever the data were sufficiently exact, I have assigned the intensity of each separate shock on the arbitrary scale of Rossi and Forel, omitting every doubtful case. The later papers of Professor Rockwood already contained this datum. Omitting all doubtful cases, I found 948 shocks at 214 different stations in California which had been so well

reported as to allow an intensity on the scale, to be assigned with certainty. In San Francisco, 417 shocks in all have been recorded. Of these, 200 were accurately described.

The Rossi-Forel Scale.

I. Microseismic shock—recorded by a single seismograph, or by seismographs of the same model, but not putting seismographs of different patterns in motion; reported by experienced observers only.

II. Shock recorded by several seismographs of different patterns; reported by a small number of persons at rest.

III. Shock reported by a number of persons at rest; duration or direction noted.

IV. Shock reported by persons in motion; shaking of movable objects, doors and windows, cracking of ceilings.

V. Shock felt generally by every one; furniture shaken; some bells rung.

VI. General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings.

VII. Overturning of loose objects; fall of plaster; striking of church bells; general fright, without damage to buildings.

VIII. Fall of chimneys; cracks in the walls of buildings.

IX. Partial or total destruction of some buildings.

X. Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

Determination of the mechanical equivalent of each degree on the Rossi-Forel scale.

It is necessary to determine the value of each degree on the Rossi-Forel scale in terms of some natural units. This it is impossible to do with exactness, owing to the nature of the subject, and it is somewhat difficult to get results sufficiently exact to be used in practice.

Referring to the Rossi-Forel scale, we find that degrees I, II, III correspond to the *feelings* of the observer—to his sensations. The rest of the scale (IV–X) refers chiefly to the effects of the shock in producing motion upon inanimate matter. The problem is to get some kind of a common unit of a mechanical sort, and to express the various degrees of the scale in terms of this unit. There is no question as to what unit to employ. The researches of the Japanese seismologists have abundantly shown that the destruction of buildings, etc., is proportional to the acceleration produced by the earthquake shock itself in a mass connected with the earth's surface.

The earthquake motion is a wave-motion, and although it is not simple harmonic, it is necessary to assume it to be such to obtain a basis for computation. We assume then a = amplitude of the largest wave; T = period of the largest wave; $V = \frac{2\pi a}{T}$ = velocity of the impulse given by the shock; $I = \frac{V^2}{a} = 4\pi^2 \cdot \frac{a}{T^2}$ = intensity of the shock, defined mechanically

= destructive effect = the maximum acceleration due to the impulse.

It would be logical to express I in fractions of the acceleration due to gravity, *i. e.*, 9810^{mm} per 1^{s}. As these fractions are usually small, it is convenient to give the values of I in terms of millimeters per 1^{s}.

The observations of Ewing, Milne and Sekiya on Japanese earthquakes give for each shock a and T, from which V and I can be computed. Very frequently a description of the effects of the shock on buildings, etc., is given by them, which description is often sufficiently minute to justify the characterization of the shock by one of the degrees of the Rossi-Forel scale.

I have carefully examined all the writings of the three gentlemen named, accessible to me, and after rejecting all doubtful cases, I have found twenty-one shocks ranging in intensity from I to IX, in which the a and T were determined by instruments and in which I could assign the Rossi-Forel intensity with confidence. The following table is the result:

*Equivalents of the degrees of intensity of Earthquake shocks on the Rossi-Forel scale, in terms of the acceleration due to the velocity of the shock itself.**

$$I = \frac{V^2}{a} = \frac{2\pi a}{T^2}$$

Rossi-Forel Scale.	Intensity.	Diff.
I	corresponds to 20^{mm} per 1^{s}	----
II	" 40 "	(20)
III	" 60 "	(20)
IV	" 80 "	(20)
V	" 110 "	(30)
VI	" 150 "	(40)
VII	" 300 "	(150)
VIII	" 500 "	(200)
IX	" 1200 "	(700)

So far as I know, this is the best determination possible from the meager data now available.

The observations at Berkeley and Mt. Hamilton are especially directed toward obtaining better values of these relations. A few years of observations will determine them, at least for the lighter shocks (I–VI).

* It is interesting to observe the influence of long period in diminishing the destructive effect of a shock of given amplitude. Thus a shock of intensity VIII has $I = \frac{4\pi^2 a}{T^2} = 500^{mm}$ per 1^{s} by observation. If $T = 0{\cdot}1^{s}$, $a = 0{\cdot}1^{mm}$, while if $T = 1^{s}$, $a = 13^{mm}$, and so for other cases.

Absolute intensity of Earthquake action at San Francisco.

417 shocks of all intensities have been recorded at San Francisco in the years 1808–1888. Of these, 200 were described so definitely that their intensities could be assigned on the Rossi-Forel scale with tolerable certainty. This work has been done with great care and is summarized in the following table:

No. of shocks actually recorded at San Francisco (1808–1888) *for which the intensity is known.*

Intensity on Rossi-Forel Scale.	Number of Shocks.
I	8
II	4
III	55
IV	50
V	58
VI	12
VII	4
VIII	7
IX	2
Total,	200

Beside the 200 shocks of known intensity, there are 217 shocks printed in my catalogue. No doubt a great number of the lighter shocks (I, II, III,) are not recorded at all.

Earthquake action is so irregular and lawless, that it is not possible to make any estimate however rough of the number of these lighter shocks. Experience has amply proved that the average intensity of San Francisco shocks is not above IV on the Rossi-Forel scale. The vast majority of our shocks are II and III and the average is certainly below IV. I shall, therefore, assume this fact as a basis for computation.

The 200 shocks of known intensity are evaluated and summed up in the following table:

							Units of Acceleration.
8	shocks of intensity	I	correspond to	8 ×	20	=	160
4	" "	II	" "	4 ×	40	=	160
55	" "	III	" "	55 ×	60	=	3300
50	" "	IV	" "	50 ×	80	=	4000
58	" "	V	" "	58 ×	110	=	6380
12	" "	VI	" "	12 ×	150	=	1800
4	" "	VII	" "	4 ×	300	=	1200
7	" "	VIII	" "	7 ×	500	=	3500
2	" "	IX	" "	2 ×	1200	=	2400
200 recorded shocks of known intensities correspond to							22900 units.

The *average recorded* shock corresponds to I = 114 units or approximately to V on the scale. This simply proves that all, or nearly all, the shocks of intensity V and more severe have been recorded and that the lighter shocks have been neglected.

As has been said 417 shocks in all have been noted (of which only 200 are accurately described). I assume the 217 shocks of

unknown intensities to have had between 48 and 49 units of intensity each, or 10460 units in all. This amounts to supposing our average shock to be of intensity IV.

In this way the table will stand:

	Units of Acceleration.
217 shocks of unknown intensity give	10460
200 " " known intensity give	22900
417 shocks recorded (1808–1888) give	33360

The average shock is of intensity IV corresponding to 80 units or to $\frac{1}{123}$d part of the acceleration due to gravity. The total intensity of 33360 units has been experienced in 80 years and corresponds to 3·4 the acceleration due to gravity. That is if all the earthquake force which has been expended in San Francisco during the past 80 years were concentrated so as to act at a single instant, it would be capable of producing an acceleration of 3·4 times that of gravity or about 109 feet per second.

The total earthquake intensity during the 80 years is nearly equal to the intensity of 28 separate shocks as severe as that of 1868, but it has been doled out so gently and gradually that we have scarcely known of it.

On the average 392 units of intensity have been developed during each one of the 80 years (1808–88). This will allow for six shocks of intensity III per year or one every two months. In fact 417 shocks have been recorded in the 960 months.

I believe that my earthquake catalogue as printed and the present note, contain nearly all the precise information which can be extracted from our past records, at this time.

The automatic earthquake registers now in use at the University of California, Berkeley (under the care of Professors Le Conte and Soulé) and at the Lick Observatory, Mount Hamilton, will afford valuable data after a few years.

I am greatly in hopes that the chiefs of the U. S. Geological Survey and of the U. S. Signal Bureau may find it practicable to establish and care for seismometric stations in the state. The cost of such stations is small. I find that the excellent duplex-pendulum instrument of Professor Ewing can be satisfactorily duplicated for $15. The California Electric Works, 35 Market street, San Francisco, is now prepared to furnish such instruments at that price. If a sufficient number of stations can be established in California, it seems to me that we may look forward to the collection of data of real theoretical and of some practical importance within comparatively few years.

Art. XXXVII.—*On the relation of the Laramie Group to earlier and later Formations;* by Charles A. White.

[Published by permission of the Director of the U. S. Geological Survey.]

While some geologists and paleontologists have claimed the Laramie Group as belonging to the Tertiary, others have as earnestly asserted its Cretaceous age. In the course of my own investigations I have found so many of the paleontological characteristics of that formation to be of little or no value as indicating its age, and other evidence to be so conflicting in character,* that, in my somewhat numerous writings concerning that group, I have hitherto treated it as representing a gradual transition from the Cretaceous to the Tertiary. Investigations concerning the physical conditions which attended the deposition of that great group of strata, and the biological conditions which prevailed during its accumulation are certainly of far more importance than the mere question of its contemporaneity with other formations, which, as regards any formation, can at best be learned only approximately. Still this latter question is by no means a trifling one, and any facts bearing upon it ought to receive due consideration. The object of this article is to record certain lately acquired facts relating to this question, and to present the bearing upon it of others which have before been published.

During the twelve years preceding the autumn of 1887, in which I had made extensive studies and observations concerning the Laramie Group, I was never able to obtain any personal knowledge of the actual stratigraphical relation of that group to any of the marine Tertiary groups which border various portions of North America. I had studied the Laramie in numerous districts from the State of Nuevo Leon, Mexico, on the south to northern Montana on the north; and wherever the base of the formation was observable it was found to rest directly and conformably upon the uppermost of the marine Cretaceous formations.† Furthermore, wherever any strata were found resting upon the Laramie they were always those of the great fresh-water Tertiary series; but I had not then traced the Laramie into a district within which marine Tertiary strata were known to exist. That is, in tra-

* See White, C. A., On the commingling of ancient faunal and modern floral types in the Laramie Group. This Journal, III, vol. xxvi, pp. 120–123.

† For an account of the intimate stratigraphical relation of the Laramie to the marine Cretaceous formation next beneath it; and of a partial faunal connection of the Laramie with freshwater Tertiary formation next above it, see this Journal, III, vol. xxxiii, pp. 364–374.

cing the Laramie into Mexico I had followed the trend of that formation from the north, and thus passed to the westward of the outcrops of the Gulf Tertiaries.

In 1884, Professor E. D. Cope announced that he had found "the Claiborne beds resting immediately upon the Laramie at Laredo,"* Texas; but he then mentioned no correlated facts in support of this important announcement and, so far as I am aware, none have since been published. The known southeastward trend of the Laramie, and the circling, and therefore converging, trend of the Gulf series of formations made it evident that the district traversed by the lower Rio Grande would be found to be the most promising field in which to search for the stratigraphical relation between the Laramie and the Eocene Tertiary. With this object in view, I last autumn visited that region and had the satisfaction of confirming the observation previously made by Professor Cope.

Starting at Eagle Pass, Texas, I proceeded down upon the Texan side of the valley of the Rio Grande to Laredo, making observations by the way. The strata representing the Fox Hills Group of the western section and the Ripley Group of the eastern, were found to dip gradually in the direction of the course of the river, and to receive those of the Laramie Group upon them, the older strata passing finally from view in that direction.

The strata which are exposed in the bluffs along the left bank of the Rio Grande from twenty-five to thirty miles above Laredo, and which bear one or more workable beds of coal there, are referred confidently to the Laramie, although they afforded me only a few imperfect fossils. These strata dip gradually to the southeastward or approximately in the direction of the river's course, and disappear beneath the sandy strata of the Eocene Tertiary some ten or twelve miles above Laredo. Below this, and all around Laredo, the strata which I found exposed are of Eocene age; and in many places they bear an abundance of characteristic fossils.

Going westward from Laredo to Lampazos in Mexico, I was able to recognize the Eocene strata for a distance of about twenty miles, beyond which the underlying rocks are so fully obscured by the debris of the plain that no exposures were observed until the neighborhood of Lampazos was reached. The known presence of Laramie strata, a few miles to the northward of Lampazos, which bear characteristic molluscan fossils of that formation, however, leaves no room for doubt that the Laramie is overlaid by the Eocene upon the Mexican side of the Rio Grande, just as it is upon the Texan side.

* Proc. Am. Philos. Soc., vol. xxi, p. 615.

While I have no doubt as to the Laramie age of the strata referred to, which I observed on both sides of the Rio Grande, and none as to the Eocene age of the strata which I found overlying them, I am by no means certain that the lowermost strata which I found resting upon the Laramie near Laredo represent the lowermost strata of the Eocene division of the Gulf series. Indeed, so far as I could discover, no equivalent of the "Northern Lignite" the lowermost member of the Eocene of Hilgard's Mississippi section, exists in the region round about Laredo, unless the coal-bearing strata of the upper portion of the Laramie are really its equivalent. I am disposed to accept this view of the case, and to regard the Northern Lignite of the Mississippi section and its equivalents elsewhere, including the uppermost strata of the Laramie, as really of Eocene age.

Those lignitic beds in the State of Mississippi and in eastern Texas rest directly upon the Ripley Group, the uppermost of the marine Cretaceous series of the Gulf region, just as the Laramie rests upon the equivalent of the Fox Hills and Ripley Groups in western Texas. But the faunal hiatus between the Ripley and marine Eocene beds in those eastern regions is so great that one may reasonably suppose it to represent sufficient time for the deposition of a larger and more important formation than the lignitic beds alone constitute there; such a formation, for example, as is the Laramie Group. Still, the fact remains that the Laramie Group as a whole is, in the valley of the lower Rio Grande, overlaid by strata which all agree to be of Eocene age. This fact makes it certain that the Laramie Group as a whole is older than certain well marked Eocene strata; and it is also presumptive evidence of the Cretaceous age of at least the greater part of the Laramie. There are also other facts pointing to the same conclusion which will be discussed in the following paragraphs.

Several years ago, Dr. G. M. Dawson announced the existence, in that portion of British America which is in large part drained by the Saskatchewan River and its tributaries, of a formation in the Cretaceous series which had not before been recognized, and to which he gave the name of "Belly River series." Since then both he and other members of the Canadian Geological Survey have from time to time published accounts of the same formation.* They report this formation as resting upon the equivalent of the combined Benton and Niobrara groups of Meek & Hayden's section of the Upper

*See Dawson, Geo. M., Geol. and Nat. Hist. Survey Canada for 1882–83–84. C. pp. 1–169. Dawson, Geo. M., ib. for 1885, B. p. 166. McConnell, R. G., ib. for 1885, C. pp. 1–85. Whiteaves, J. F., Contributions to Canadian Paleontology, vol. i, Part I, 1885.

Missouri Cretaceous, and as underlying strata which bear molluscan forms such as characterize the Pierre and Fox Hills groups of the same section.

The fossils which they report as coming from the Belly River formation are wholly different from those that characterize the formations which underlie it, as well as the one which immediately overlies it. Their collections not only indicate the absence of true marine forms from the Belly River formation, and the presence in it of remains of both vertebrate* and invertebrate† faunas which are similar to those of the Laramie, but they contain a considerable number of molluscan forms which are specifically identical with a part of those which characterize the Laramie Group.

Those geologists furthermore report that the marine Cretaceous strata which overlie the Belly River formation are, in turn overlaid by true Laramie strata, bearing the characteristic fossils of that formation. The following table shows the relation of the foremention formations, with one another; and also the relation of Dr. Dawson's section with the Upper Missouri section of Meek & Hayden.

Meek and Hayden.	Dawson.‡
Judith River beds [Laramie]	Laramie.
No. 5. Fox Hills Group No. 4. Fort Pierre Group	Fox Hills and Pierre.§
Wanting	Belly River beds.
No. 3. Niobrara Group No. 2. Ft. Benton Group	Benton and (Niobrara)?
No. 1. Dakota Group	Dakota; and upper part of Kootanie.

Considerable paleontological difference between the combined Benton and Niobrara groups beneath, and the Pierre and Fox Hills groups above, has long been known to exist. In recognition of this difference Meek designated the two divisions respectively, as the "upper" and "lower series"; and as "Earlier and Later Cretaceous." Still, those formations have been generally regarded by geologists as forming a continuous series of marine deposits which was unbroken as such until the

* Professor E. D. Cope has examined collections of vertebrate remains from the Belly River formations, and has personally informed me that they consist wholly of Laramie types.

† See Cont. Canadian Paleontology, vol. i, Part I, pp. 55–77; and plates IX and X.

‡ See Ann. Rep. Geol. and Nat. Hist. Surv. Canada for 1885, p. 166, B.

§ It will be seen that Dr. Dawson combines together the Fox Hills and Pierre, and also the Benton and Niobrara divisions, recognizing only a single formation in each of the two cases. This combination has also long been adopted by members of the U. S. Geological Survey, on the ground that there is no sufficient reason for separating them except for occasional local study.

uppermost one received upon it the great brackish- and-fresh-water Laramie formation. Therefore the first announcement of Dr. Dawson's discovery was received with not a little surprise by the geologists who had studied the formations referred to in more southern regions.

I have never visited the Saskatchewan region and cannot therefore speak of the formations there from personal observation. But after carefully reading the accounts which have been published by the Canadian geologists, and having had gratifying personal interviews upon the subject with both Dr. Dawson and Mr. Whiteaves, I can now see no good reason to doubt the correctness of their observations. Accepting their conclusions, it appears that in the region referred to, the deposition of marine Cretaceous strata was interrupted at the close of the Niobrara epoch by such a change in physical conditions as caused the introduction upon the area which had been occupied by marine waters of a brackish- and fresh-water formation similar to the Laramie. It also appears that upon the completion of that brackish- and fresh-water formation, marine conditions, similar to the first, were resumed; and the Pierre-Fox Hills formation was then deposited. Furthermore, upon the completion of the last named formation, brackish- and fresh-water conditions were resumed, over the same area, when the Laramie Group was deposited.

The specific identity of a considerable part of the molluscan fauna of the Belly River formation with Laramie forms makes it necessary to assume that both faunas had a common origin. This proposition being accepted, the stratigraphical relation of the Belly River formation with the Laramie makes it further necessary to assume that at least a large part of the fauna of the Laramie was derived directly from that of the Belly River formation.

The introduction of a true marine formation between the two which are of brackish and-fresh-water origin precludes the supposition that the earlier fauna prevailed over the same area which it first occupied during the deposition of that marine formation. The presence of certain identical species in both the Belly River and Laramie formations is presumptive proof that those species somehow and somewhere survived during the time that the Pierre-Fox Hills formation was in course of deposition. The absence of any equivalent of the Belly River formation from the marine Cretaceous series which so extensively prevails to the southward of the Missouri river seems to indicate that the molluscan fauna of that formation originated in that northern region, and that it did not then extend far to the southward.

The species referred to were gill-bearing mollusca, and to have survived they must have had a continuously congenial habitat. That is, they were in part fresh-water and in part brackish-water forms, and those respective conditions of the waters in which they lived must have been somewhere continuous to have made the survival of those species possible. It is therefore probable that the Belly River and Laramie faunas somewhere became blended together as one, upon the final retirement of the marine Cretaceous waters; although no such blending of the strata of those formations has yet been discovered. Whatever may have been the facts in the case, the specific identity of those Belly River and Laramie mollusca makes it necessary to assume that at least a considerable part of the Laramie molluscan fauna began its existence long before the close of the Cretaceous period as it is represented by marine formations. This faunal relationship between the Belly River and Laramie formations also strongly connects the latter formation with the Cretaceous.

The two categories of facts relating to stratigraphical relations of the Laramie which have been presented in the preceding paragraphs of this article, and which are strongly suggestive of its Cretaceous age, have not before been publicly discussed in that connection. There are however two other categories, one relating to physical, and the other to paleontological phenomena which have been much discussed, both of which have been held by many persons to prove conclusively the Cretaceous age of the Laramie. The paleontological fact which has most influenced the views referred to, and the only one that need be mentioned here, is the occurrence of dinosaurian remains in the Laramie, extending even to some of its uppermost strata.

The physical phenomena referred to pertain to certain of the orogenic and epirogenic* movements which have taken place within the great region occupied by the Laramie Group. The movements referred to are those which on the one hand have resulted in the present elevation of that great western portion of North America, and on the other, in such great folds, for example, as those out of which the Uinta, and Rocky Mountains have been carved. In at least the greater part, and apparently all, of those movements the Laramie Group is found to have been fully involved together with all the formations beneath it; while the later formations were not so fully involved. Thus there appears to have been within that region no physical break in the continuous accumulation of material composing the true marine Cretaceous formations, and none of importance until the close of the Laramie period, if we ex-

* Etym. Ηπειρος; mainland, or continent.

cept the great hiatus which probably exists between the Carboniferous, and the Uinta Sandstone. The sedimentation also seems to have been continuous from the uppermost of the marine Cretaceous formations into the Laramie, although the faunas of these respective groups are widely different. Consequently field geologists have always experienced great difficulty, in the frequent absence of distinguishing fossils, in separating that marine Cretaceous formation from the Laramie; and they have therefore been disposed to regard the latter as a Cretaceous formation.

While I still believe that at least the upper strata of the Laramie Group represents a gradual transition from the Cretaceous to the Tertiary period, the facts which have been presented in the preceding paragraphs certainly constitute strong presumptive evidence of the Cretaceous age of the greater part of it. Judging from my own investigations, it is regarded as impossible to draw either a paleontological or a stratigraphical dividing line between the Cretaceous and Tertiary portions of the Laramie Group. Therefore the established custom of geologists in formulating a scheme of classification of the formations, seems to require that the whole group should be classed either as Cretaceous or Tertiary. It is not only conceivable, but it is natural to suppose, that a transitional formation might possess characteristics which, so far as evidence of age is concerned, would be nearly equally balanced between two periods. I believe the Chico-Téjon series of California, for example, actually presents just such a case. The evidence, as a whole in the case of the Laramie however does not appear to be so well balanced, and in my future writings I shall probably class the Laramie as a Cretaceous formation; although I shall regard this practice as little more than a matter of conventional convenience.

ART. XXXVIII.—*The Gabbros and Diorites of the "Cortlandt Series" on the Hudson River near Peekskill, N. Y.;* by GEORGE H. WILLIAMS.

IN two former papers* I have described two types—peridotites and norites—which form members of that complex group of massive rocks occurring in the northwestern corner of Westchester County, N. Y., and designated by Prof. J. D. Dana as the "Cortlandt Series." The area occupied by these rocks—about twenty-five square miles in extent and nearly coincident

* This Journal, III, xxxi, Jan. 1886, p. 26; ib., xxxiii, Feb. and March, 1887, p. 135 and p. 191.

with Cortlandt township—is mainly composed of norite, the many varieties of which were described in my last paper. In the southeastern and southwestern corners of the township, as well as on Stony Point on the opposite side of the Hudson River, olivine-norites and peridotites are found, while at other localities, mostly in the southwestern portion of the area, still different but closely allied types of massive rocks occur. These, which form the subject of the present communication, are :—

Class III, Gabbro,
Class IV, Diorite,
Class V, Mica-Diorite.

These rocks are everywhere connected so closely by intermediate forms that they may, to a certain extent, be regarded as facies of the norite. Indeed, even in the types most widely removed from the prevailing rock hypersthene is very liable to recur. There are enough general resemblances and connecting links to join all the rocks of this series into a geological unit; and at the same time there are differences sufficient to show that many types were successively produced from the same igneous focus.

Class III. Gabbro (*von Buch.*)

1. *Gabbro proper.*—This rock is to be found at only a few isolated localities, of which the most representative is "Munger's Corners," a short distance west of Montrose Station on the N. Y. C. & H. R. R. Prof. Dana has designated this place as "*g*" on his map, and describes the occurrence as "a grayish white augitic rock."* It is represented by several slides in both Prof. Dana's and the Johns Hopkins University collection. (No. 42 and K, Mt. 13 (D)).

Under the microscope this rock appears as an aggregate of allotriomorphous plagioclase and augite grains. The latter mineral is of a reddish or grayish color, both often appearing in the same crystal individual. It is without pleochroism and frequently shows a pronounced orthopinacoidal parting. The substance of the augite or diallage is for the most part unaltered, although a little green uralite is occasionally developed. Accessory constituents in this rock are biotite, apatite, ilmenite and sphene. The last named mineral is quite abundantly represented in all sections and appears to have resulted from the alteration of the titanic iron.

The gabbro shows evidence of great dynamic action. The twinning lamellæ of the plagioclase are much curved and both

* This Journal, III, xx, p. 195, and p. 211, Sept. 1880.

the feldspar and the augite are often peripherally granulated by crushing and rubbing.

Another rock (No. 44) occurring at Centerville on the south side of Prof. Dana's limestone 4,* is in all respects identical with the gabbro at Munger's Corners.

The eruptive dykes which occur in such intimate association with the limestone at the southern end of Verplanck Point, are in part gabbros; in part mica- or hornblende diorites. No. 111, from one of the narrowest of these dikes, is quite like the gabbros last described, except that it is finer grained. Its augite also is more extensively changed to uralite. The thin section of this specimen includes some of the limestone in contact with the eruptive rock. This is altered by the metamorphic action into a granular aggregate of pale green pyroxene together with some pale hornblende and pleonaste.

2. *Mica-Gabbro.*—The presence of accessory biotite in the gabbros has been mentioned above; in some cases this mineral becomes so largely developed as to equal or even exceed the amount of augite present. Thus No. 109 and VK 5, of Prof. Dana's collection, both from dikes at Verplanck Point, differ only from the normal gabbro of this locality in the increased amount of biotite present. No. 45 also is only a biotite modification of the Centerville gabbro above mentioned.

The most interesting point in regard to the gabbros of the Cortlandt Area is that they always (so far as observations yet extend), *occur immediately beside limestone.* They seem to represent a local modification of the norite produced by an increase of lime, for this, as is well known, would change the orthorhombic magnesian hypersthene to a monoclinic pyroxene.

Class IV. Diorite. (*Haüy.*)

The hornblende, which imparts the essential character to this class of rocks, is compact and homogeneous in structure, possessing every appearance of a primary constituent. It occurs in allotriomorphous individuals which vary in size according to the coarseness of the rock-grain. In the main this hornblende is identical with that already described at length from the hornblende-peridotite of Stony Point.† In some instances this hornblende contains the same delicate inclusions, while in others these are totally wanting. Its pleochroism is always strong, and its color either a deep chestnut brown or a bright green. More rarely it shows by transmitted light a color intermediate between these two.

* Vid. the map in Prof. Dana's article. This Journal, III, xx, p. 195, Sept., 1880.

† This Journal, III, xxxi, p. 31, Jan. 1886.

The two types of diorite produced by the presence of brown or of green hornblende are quite distinct both in their occurrence and relationships. The former is always associated with pyroxene rocks and tends to pass gradually into norite, gabbro, or pyroxenite; by a total loss of feldspar these diorites may also develop into massive hornblendites. The diorites composed of green hornblende, on the other hand, show their closest relationship to the mica-bearing rocks.

The grain of these diorites varies extremely, from aphanitic varieties to such as have hornblende individuals over six inches in length.

1. *Brown-hornblende-Diorite.*—This type is best developed in the wonderfully complicated net-work of massive rocks exposed on the river bank along the northern portion of Montrose Point. The brown diorite is most intimately associated with norite, and grades, on the one hand into this, and on the other into a massive brown hornblendite. The other constituents are triclinic feldspar (presumably the same *andesine* as occurs in the norites),* apatite and magnetite. Accessory hypersthene is common by which the diorite shows its tendency to grade into the norite.

The brown diorites extend, with exactly the same associations, eastward from Montrose Point nearly as far as Montrose Station, as is shown by a large number of sections in both the University and in Prof. Dana's collection. They were, however, not encountered in other parts of the Cortlandt Area.

2. *Hornblendite.*—Both coarse- and fine-grained aggregates of compact brown hornblende occur abundantly along the northern portion of Montrose Point. These rocks have a glistening black color and are most intimately associated with the norites, hyperites, diorites, and pyroxenites which also occur there. No more complicated interpenetration of eruptive rock-types could possibly be imagined than is displayed at this locality—every rock includes and forms dykes in every other; and at the same time every type passes by gradual changes in its mineralogical composition into every other one!

The striking examples of the passage by paramorphism of pyroxene into compact brown hornblende described some time since by the writer,† occur in rocks from Montrose Point intermediate between pyroxenite and hornblendite. The origin of the brown hornblende from both the diallage and the hypersthene is so apparent as to suggest the derivation of all the hornblendites by paramorphism from preëxistent pyroxenites.

* This Journal, III, xxxiii, p. 140, Feb., 1886.

† This Journal, III, xxviii, p. 261, et seq., Oct., 1884.

Specimen Mt. 7 of Prof. Dana's collection is interesting as illustrating the alterations which one of the coarser hornblendites from Montrose Point has undergone. The change of the brown hornblende is to serpentine and talc.

Hornblendite composed entirely of green hornblende is rare within the Cortlandt Area. It does, however, occur among the dykes intersecting the limestone at Verplanck Point, as shown in section VK.1. of Prof. Dana's collection.

3. *Green-hornblende-Diorite.*—Typical diorites of this class are not common in the Cortlandt Area. Those observed occur in narrow dykes on Montrose or Verplanck Points. These diorites which are wholly free from biotite always contain a hornblende, which, though it may properly be called green, has nevertheless a decidedly brownish tinge. On the whole the relationship of these rocks with the brown hornblende diorites is much closer than it is to those of the following class.

By far the most typical development of the green-hornblende diorites belonging to the "Cortlandt Series," occurs along the edge of the steep rock-wall which extends westward from Cruger's Station, toward Montrose Point. This abrupt ascent marks the contact between the massive rocks and the softer, though much metamorphosed schists. These diorites, however, always carry a large amount of biotite and therefore are more properly classed as

4. *Mica-hornblende-Diorites.*—The association between this type and the pure mica-diorite (class V) is extremely intimate and there is everywhere observable a tendency toward the development of the latter rock by the total replacement of the hornblende by the biotite.

The most prominent microscopical peculiarity of these green diorites is their sudden and extreme alterations of grain; very coarse and fine varieties occurring side by side in the same exposure, in a manner unequalled in any other part of the entire Cortlandt Area. The best locality to observe this structure is just above the brick-sheds near Cruger's Station, at a point marked "*p*" on Professor Dana's map.*

The constant mineral constituents of these diorites are a finely striated plagioclase, green compact hornblende, biotite, magnetite, epidote and apatite. Less abundant are an unstriated feldspar (orthoclase) and quartz. Garnet is a frequent endo-metamorphic product near the contact of the diorite with the schists. The hornblende differs only in its color from the compact brown hornblende already described in other members of the "Cortlandt Series." It occurs in irregular individuals which are filled with magnetite inclusions. The color is a deep green, often inclining to bluish-green, and the pleochroism is very intense.

* Loc. cit.

All the other constituents of the coarse hornblende-mica-diorites of Cruger's Point are identical with those of the typical and more abundant mica-diorite. They may therefore best be described in connection with this rock (class V), of which indeed the type now under consideration is only a particular facies.

A very fine-grained variety of the hornblende-mica-diorite is quite common as a dike rock on both Montrose and Stony Points. In many respects this presents a resemblance to Rosenbusch's group of *dioritic lamprophyres* or *kersantites*, and yet its extreme freshness and freedom from calcite, the frequently granular form of the feldspar, and the association in nearly equal proportions of biotite and green hornblende while augite is wholly wanting, separate this rock from any of the many varieties of kersantite described in Rosenbusch's recent work. The fine-grained, dark-gray dikes of this rock may be most advantageously seen in the cuttings on the West Shore Railroad through and near Stony Point. Here they intersect the much contorted schists, the peridotite and the mica-diorite and afford the evidence upon which Professor Dana admitted the truly eruptive nature of at least the more basic members of the "Cortlandt Series."* These dikes are, however, shown by the microscope to belong to the more acid rather than to the more basic of the massive rocks.

Class V. Mica-Diorite.

This rock is more uniform in its character than any other of the important members of the Cortlandt Series. It is in all cases essentially a rather coarse-grained aggregate of plagioclase and biotite, with accessory epidote, apatite and magnetite; often a little orthoclase and quartz; and sometimes garnet. The latter mineral is an endo-metamorphic product, and is to be found only near the contact with the schists.

The mica-diorite occurs only in the south-western part of the Cortlandt area; on the east side of the Hudson River west of Cruger's station, and on the west side at Stony Point (see map in my paper on the Cortlandt Peridotite, this Journal, Jan., 1886, p. 29).

No such pure type of mica-diorite† has ever, to my knowledge, been described from any locality.

* This Journal, III, xxviii, p. 384. Nov., 1884.

† Professor J. D. Dana called this rock *soda-granite*, (this Journal, III, xx, p. 198), and later *hemi-dioryte*, (ib., xxv, p. 478). The first name was proposed by Haughton in 1856 to designate, as it still does, a true granite in which the soda is in excess of the potash, (cf. A. Gerhard, Neues Jahrb. für Min., etc., 1887, II,

I have as yet been unable to secure a complete analysis of this rock, but an average of four determinations of its silica gives 53·94 per cent. This is sufficient of itself to establish the dioritic nature of the rock.

The feldspathic constituent varies considerably in composition as may be seen from the different extinction-angles occurring even in the same individual; nevertheless a number of specific gravity determinations, lying between 2·67 and 2·648, show that the mineral belongs to the oligoclase-andesine series. Some of this plagioclase is notable for being almost free from twinning striation. This is especially true for section No. 87, from Stony Point, whose feldspar was particularly studied. In other cases the striation is finely displayed, not infrequently according to both the albite and pericline laws. A zonal structure is common, and the delicate inclusions described in detail in the feldspars of the norites,* are sometimes abundant and sometimes absent.

The mica, which constitutes the only other essential constituent of these rocks, is a biotite very rich in iron. Its absorption is intense and basal sections are only translucent when very thin. Their color is then a greenish-brown. The optical angle is so small that it is impossible to determine whether the mineral is anomite or meroxene. The mica contains no other inclusions than magnetite grains and apatite needles. None of the pleochroic aureoles so common in the granites were observed.

The presence of orthoclase was not positively substantiated in these rocks. An unstriated plagioclase might easily be mistaken for orthoclase.

Quartz occurs sparingly in grains, which, from their allotriomorphous character, were evidently the last product of crystallization. These are frequently penetrated in every direction by the minute and indeterminate black needles mentioned by Hawes, Rosenbusch and others.

Magnetite is universally distributed. Apatite occurs in rare abundance, size and perfection. Sphene and zircon are often present, and epidote of somewhat exceptional character is very common, especially in the mica-diorite from Stony Point. This mineral is of a pale green color, without pleochroism and its

p. 267). Prof. Dana objects to the term mica-diorite, because (1) the original diorite was a hornblende rock and (2) because hornblende and mica are widely different minerals. It must, however, be remembered that, although these two minerals are so different, they play a very similar *rôle* in rock-composition. The name mica-diorite is here retained because, in spite of all objections to it, it has the very great advantage of being readily intelligible to students of petrography the world over,—something that cannot be said of any other term which might be proposed in its place.

* This Journal, III, xxxiii, p. 141, Feb., 1887.

source cannot be traced in the alteration of any older constituent. It is generally without terminations but is most remarkable for the peculiar eaten or corroded aspect presented by the crystals, (see fig.) These are often divided into the most complicated fret-work of interlocking tongues. The cleavage is parallel to the long direction of the crystal, and the extinction is parallel to the cleavage lines. The mineral is shown to be epidote and not a pale pyroxene, by the fact that the plane of the optic axes is perpendicular to the cleavage lines. Twin crystals of this epidote occur as shown in the figure.

Epidote in Mica-Diorite (No. 28.)

The bright red garnet crystals which are so often found in this rock are most frequent near the edge of its mass and are doubtless an endo-metamorphic product.

The structure of the mica-diorite is hyp-idiomorphous in the sense of Rosenbusch. It is most closely connected with the diorite proper, into which it grades through the mica-hornblende-diorites as explained above. On the other hand, it passes into the norites through the group of the mica-norites.* Some of these rocks contain much more biotite than hypersthene, closely resembling the hypersthene-bearing mica-diorite from Campo Major in Portugal described by Merian† and the norite facies of the Klausen diorite mass described by Teller and von John.‡ In the latter rock the feldspar has also been shown to belong to the andesine series.

Quartz-Mica-Diorite.—A quite exceptional member of the massive rocks of the "Cortlandt Series" occurs a short distance eastward of Montrose Station. This has a very light color with only comparatively rare and small flakes of biotite scattered through it. It forms a bed of moderate thickness within the dark massive norite against which it is sharply defined, i. e., there is here nothing like a gradual transition from the one rock to the other.

Professor Dana has described this rock as a granitoid mica-

* This Journal, III, xxxiii, p. 191, March, 1887.
† Neues Jahrbuch für Min., etc., Beil. Bd. III, p. 292, 1885.
‡ Jahrb. k. k. geol. Reichsanst., xxxii, p. 589, 1882.

ceous quartzite,* but a careful petrographical study of it shows that it is a massive rock, best to be designated as a *porphyritic quartz-mica-diorite.*

Under the microscope well-formed crystals of feldspar are seen imbedded in a rather coarse-grained groundmass composed mostly of quartz and feldspar. The porphyritic crystals possess a beautiful zonal structure and sometimes, though not commonly, polysynthetic twinning striation. No porphyritic quartz occurs.

The groundmass is a mosaic of interlocking grains unlike the structure of a quartzite. It contains biotite and epidote exactly like that characteristic of the mica-diorite proper, except that their amount is here much less. The feldspar of the groundmass is sometimes striated, sometimes not. Specific gravity determinations made with the Thoulet solution show all the feldspar of this rock to be plagioclase, varying between 2·63 and 2·67. This renders its separation from the quartz and the quantitative determination of the latter impossible.

This rock differs from the mica-diorite proper only in its greater amount of quartz and the proportionately smaller amount of biotite and epidote. It may be regarded as a variety of the former rock and as the most acid type of the whole "Series," which is throughout essentially a plagioclastic one.

We have now, within the limits of this and of my two former papers traced out the following types of basic and ultrabasic rock which form members of the group called by Professor Dana the "Cortlandt Series."

Class I. Peridotite.
1. Hornblende-Peridotite (Cortlandtite).
2. Augite-Peridotite (Pikrite).

Class II. Norite.
1. Norite proper.
2. Hornblende-Norite.
3. Mica-Norite.
4. Augite-Norite (Hyperite).
5. Pyroxenite.

Class III. Gabbro.
1. Gabbro proper.
2. Mica-Gabbro.

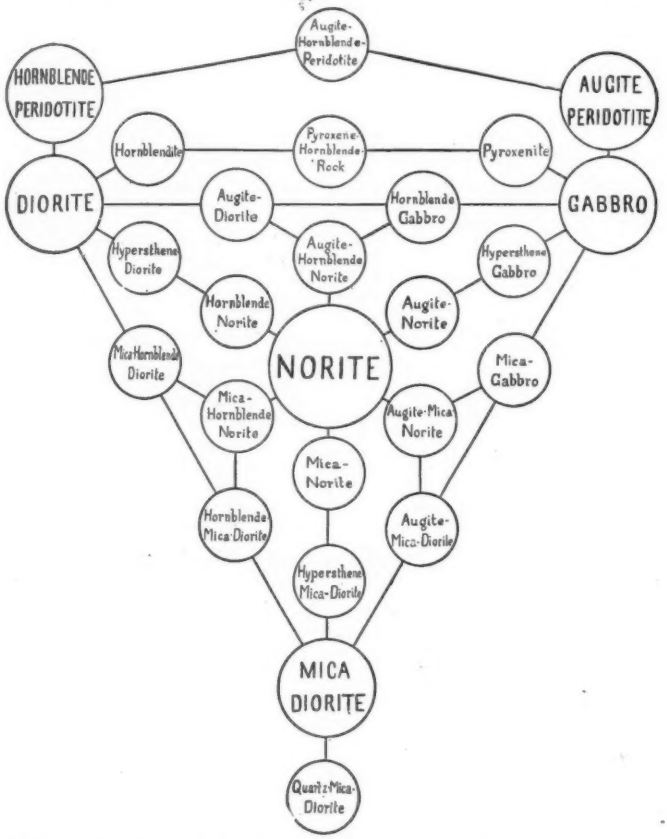
Class IV. Diorite.
1. Brown-hornblende-Diorite.
2. Hornblendite.
3. Green-hornblende-Diorite.
4. Mica-Hornblende-Diorite.

Class V. Mica-Diorite. ("Soda-granite," "Hemidioryte," Dana.)
1. Mica-Diorite proper.
2. Hornblendic Mica-Diorite.
3. Hypersthenic Mica-Diorite.
4. Quartz-Mica-Diorite.

In spite of the extent to which the subdivision of the various types has been carried in the descriptions, the actual variety of intermediate or transitional forms has not been adequately represented. In order to show more completely the

* This Journal, III, xx, p. 218, Sept., 1880.

number and relationships of these intermediate members and to connect all the various types together in one geological unit or "*Series*," the following diagram has been constructed. All



varieties represented in the circles correspond to actual specimens collected within the Cortlandt Area and many others might have justified a still more minute differentiation. The lines connecting the circles indicate the directions in which the best marked transitions take place.

These rocks present an admirable example of what are called *facies* of a geological unit mass. In spite of their great petrographical variety, they are everywhere connected by transitional forms into the closest relationship. And yet we need not regard all the rocks as having been formed simultane-

ously. The region was probably for a long time the scene of eruptive activity. At different periods different types may have been produced which broke through these already solidified. The quartz-mica-diorite near Montrose Station seems to be a later intrusion into the older and more basic norite.

This will conclude what the writer has to say on the massive rocks of the "Cortlandt Series." These are however so extremely varied that their study can hardly be said to be more than begun. It is earnestly hoped that some one may in future work out all their manifold variations and relationships more completely than the writer, at such a distance from the field, has been able to do.

Enough perhaps has already been said regarding the nature and mode of occurrence of these rocks to place their truly eruptive nature beyond all question; nevertheless all the evidence bearing on this point may be more advantageously summarized at the conclusion of the next and final paper, which will deal with the phenomena of contact metamorphism produced by the massive rocks in the adjoining schists.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, Jan. 27, 1888.

Art. XXXIX.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGee.*

(Continued from page 388.)

Résumé.—The Columbia formation consists of a series of subestuarine and submarine deltas and associated littoral deposits, occupying the entire Coastal plain of the Middle Atlantic slope up to altitudes ranging from about 100 feet in the south to over 400 feet in the north; the delta phase found at the mouths of the great rivers is bipartite, but the littoral phase overspreading the rest of the area is indivisible; its materials—which are derived largely from the Potomac formation and other local terranes and partly from the Piedmont and Appalachian regions—increase in coarseness northward, and are (in part) evidently ice-borne; it reaches greatest volume along the principal waterways and near the present coast; it is destitute of fossils at high levels and in its lower (and ice-borne) portion, but at lower levels and higher horizons yields remains of marine animals of recent and local species; it is connected with an extensive series of shore-lines and terraces;

* Plates VI and VII are issued with this number. The parenthetical clause in the second line of page 137 of this series should read *which he is disposed to refer to the Jurassic.*

and the deposits and shore-lines alike pass beneath, and are manifestly far older than, the terminal moraine.

The predominant and most significant phenomena of the formation are widespread stratified deposits and associated terraces; and if deposits are ever proof of deposition, and if shore lines ever tell of shores, the Coastal plain of the Middle Atlantic slope was submerged beneath floe-bearing oceanic waters during the Columbia period.

Synopsis of Earlier Studies.—While the isolated deposits representing it have not been correlated hitherto, and while the chronologic and taxonomic relations of its parts were never elucidated by local observers, the formation has been defined, and its genesis recognized, by every geologist who has studied its area.

W. B. Rogers was one of the first to locally discriminate the formation, and was also one of the last to discuss its relations: he recognized it in eastern Virginia in 1835,* and in 1839 accurately diagnosed its principal characters and inferred that it was formed in an ocean subjected to strong tides and currents;† and in 1875 he described it as developed about Washington, discriminated it from the newer Mesozoic (Potomac) gravels, indicated the sources of the coarser materials, noted its increasing coarseness northward, reiterated his inference that it represents a period of submergence sufficient to fill the valleys and perhaps flood the divides of the Coastal plain, and inferred further that it was formed during a period of cold and floating ice probably coeval with the ice period of the north.‡

H. D. Rogers recognized the formation in New Jersey in 1836, and inferred that the "sand and gravel" of which it consists was of sub-aqueous origin;§ and he maintained the same inference in 1840.‖

In 1841 Booth discriminated the formation in southern Delaware, enumerated its fossils, recognized its marine origin, and referred it to the "after-Tertiary age."¶

About the same time Conrad classified the later Tertiary deposits of the Middle Atlantic slope,** described various exposures of the stratified beds of the Columbia formation and enumerated their marine fossils (which are all of recent and local species), and referred them to the "Pleistocene or post-Pliocene."

* Geology of the Virginias, 1884, 29–30.
† Ibid., 253, 264, 275.
‡ Ibid., 709–13.
§ Report Geol. Survey of N. J., 2d ed., 1836, 17.
‖ Description of the Geology of N. J., 1840, 176.
¶ Mem. Geol. Survey Del., 1841, 94, 97.
** Bull. of Proceedings of Nat. Inst. for Promotion of Sci., 1841, 177, et seq.

Mather recognized the formation on Long Island in 1843, enumerated its fossils, referred it to the "Long Island division" of the "upper secondary system,"* attributed it to a marine current flowing northward "along the eastern coast," and inferred from the paucity of organic remains and the presence of ice-borne blocks that the temperature was low during its deposition.

The formation attracted Lyell's attention during his two visits to this country: During the earlier he referred to the "post-Pliocene" "the marine shells" of eastern Georgia and South Carolina, which "differ in no way from those of the adjoining sea," "contained in deposits of clay and sand" overlain in some places by dark colored clays yielding "remains of quadrupeds of extinct species;" and concluded that at the time of deposition the land stood lower than now, while the temperature of atmosphere and ocean were little different from to-day.† During the later he discriminated the "low region bordering the Atlantic" from southern Georgia to the Neuse River in North Carolina, and made up of stratified sands and clays yielding recent marine shells from the terraces of Eocene deposits by which it is overlooked—the low plain rising but ten to forty feet above tide and extending only twenty miles inland.‡

A few years later Tuomey described the same deposit in South Carolina as "sand, clay and mud, containing fossils, some sixty feet thick," rising eight feet above tide and extending only eight or nine miles inland,§ enumerated its fossils—which are all marine and nearly all recent and local,‖—and referred it to the post-Pliocene.

The observations of Lyell and Tuomey are significant in that they indicate narrowing and lowering of the formation southward.

In 1852 Desor reviewed the paleontology of the formation as developed from South Carolina to Sancoty Head and Point Shirley, noted that the fossils are "nearly all referable to living species" and that the deposit occupies only a narrow zone rising eighteen feet above tide in the south but widening greatly and reaching an altitude of 100 feet northward,¶ and inferred not only that it is marine, but that the climate was warmer than now when it was deposited. He classed the formation as post-Pliocene, and correlated it with the "Laurentian" of Canada and New England.

* Geology of N. Y., Part I, 1843, 246, 261–8, 274–5.
† Quart. Jour. Geol. Soc., vol. ii, 1846, 405–6.
‡ Second Visit to the U. S., N. Y. 1855, vol. i, 256–61; vol. ii, 197.
§ Geology of South Carolina, 1848, 186, 188, 212.
‖ Ibid., 203–5.
¶ This Journal, II, 1852, 50–3; c. f., Proc. Boston Soc. Nat. Hist., III, 1851, 79; Mem. Boston Soc. Nat. Hist., 1866–9, 252.

In 1860 Tyson described the formation as "beds of loamy clays and sands" (supposed to rise only thirty feet above tide, but represented on the map over areas of much greater altitude) containing a few marine fossils and covering a considerable portion of peninsular Maryland, concluded that "it consists of sediments derived from" the adjacent Piedmont and Appalachian regions, and referred it to the post-Tertiary.*

In 1867 Sanderson Smith pointed out that the gravel and sand beds rising fifteen or twenty feet above tide on Gardiner's Island contain twenty-five species of fossils, of which all but two now inhabit the Atlantic waters south of Cape Cod—the general facies of the fauna indicating a lower temperature than the present, and thus disproving Desor's hasty inference of warmer climate.† Verrill more recently enumerated about sixty marine species (of which nearly all are recent and found in the immediate vicinity) from the petrographically similar and paleontologically equivalent deposits of Sancoty Head, of which those from the lower strata indicate warmer and those from the upper strata colder climate than the present—the difference being attributed to local geographic changes.‡

In 1868 Cook described the formation as clean quartz pebbles and sand, covering the whole of peninsular New Jersey up to altitudes of 300 or 400 feet,§ designated it "Drift Gravel," mentioned the "deltas" and "terraces" of which it is in part composed, and inferred not only that it is subaqueous but also, from walrus remains within it, that the period of deposition was cold.‖ Ten years later he designated it "Yellow Sand and Gravel,"¶ pointed out that it is overlain by, and distinct in material and structure from, the modified and unmodified drift connected with the terminal moraine, and (finding difficulty in ascertaining the source of the materials) suggested that "it is a wash or drift from lands now under the waves of the Atlantic."** In 1880 he described the deposit in detail, designated it "Preglacial Drift," showed that it is unconformable to the glacial drift above and the Cretaceous below,†† and repeated his inference (but only as a "possible hypothesis") that it "was the wash from land to the southeast and now buried beneath the ocean, and took place in the later Tertiary age;"‡‡ and in 1884 he figured a bowlder of it, ten tons or more in weight, imbedded in the glacial drift.§§

In 1868 Cope recorded reindeer antlers from the gravels of

* First Rep. State Ag'l Chemist of Md., 1860, 44.
† Ann. Lyc. Nat. Hist., N. Y., viii, 1867, 149–51.
‡ This Journal, III, x, 1875, 364–9.
§ Geology of New Jersey, 227, 298, 242.
‖ Ibid., 285–342.
¶ Report on Clays, 1878, 17.
** Ibid., 20.
†† Report Geol. Survey of N. J., 1880, 87.
‡‡ Ibid., 95, 96.
§§ Report Geol. Survey of N. J., 1884, 16–17.

the formation in New Jersey, and enumerated other mammalia of the "terrace epoch" apparently from the same deposit (at least in part), including *Elephas primigenius*, *Mastodon giganteus*, *Equus fraternus*, *E. complicatus*, *Dicotyles nasutus*, *Cervus Virginiana* and *C. canadensis*.*

In 1875 Kerr combined and referred to the Quaternary or post-Pliocene a succession of clays, sands, gravels, etc., covering the Coastal plain in North Carolina up to 500 feet above tide, and classified them as "Glacial," "Champlain" and "Terrace,"† finding evidence of sub-aqueous deposition (1) in structure, (2) in "littoral and estuary shells undistinguishable specifically from those now living along the shore,"‡ and (3) in terraces,§ and of coeval refrigeration (1) in bowlders and (2) in indications of soil-cap movement.‖ Further investigation led him to divide the deposits into Eocene¶ and undoubted Quaternary, the latter rising about 100 feet above tide at Weldon and elsewhere in the northern part of the State, but inclining southward nearly to sea level on Cape Fear River; and he inferred from the presence of the deposits, their structure, and their fossils of recent marine species, as well as the terraces, that the formation was laid down during a Quaternary submergence "to the extent of probably 200 feet" on the Roanoke, but diminishing to only a few feet in the southern part of the State.**

Kerr's later work is important in that it harmonizes and extends that of W. B. Rogers and others in Virginia, and that of Lyell and Tuomey in South Carolina.

In 1879 Fontaine incidentally noted certain characters of the formation, mentioned its unconformity to the Mesozoic and Tertiary deposits, recorded its presence along the Potomac, James, and Roanoke rivers up to altitudes of 60 feet, and concluded that at least a part of it was deposited during the Glacial period by aqueo-glacial agencies.††

In 1880 Lewis separated the superficial deposits of Philadelphia into (1) Brick Clay, (2) Red Gravel, (3) Black Gravel, (4) Yellow Gravel or Philadelphia Gravel, (5) Micaceous Sand, and (6) Bowlders;‡‡ and later in the same year he combined the second and third, and apparently the fifth and sixth, of these divisions under the name of "Philadelphia Red Gravel," which he referred to the Champlain, and identified the "Yellow Gravel" of New Jersey with the fourth division (then

* Geology of New Jersey, 1868, 740.

† Report Geol. Survey of North Carolina, i, 1875, 154.

‡ Ibid., 155. § Ibid., 195 [misprint for 159.] ‖ Ibid., 158.

¶ The Appomattox formation was not discriminated by Kerr, though it comprises the greater part of the deposits described.

** Jour. Elisha Mitchell Scientific Society, 1884–5, Raleigh, 1885, 83–84.

†† This Journal, III, xvii, 1879, 42–3, 50, 54.

‡‡ Proc. Acad. Nat. Sci., Philad., vol xxxii, 1880, 262.

designated "Glassboro Gravel"), which he referred to the Pliocene.* The next year he concluded more specifically (1) that the Yellow Gravel of New Jersey "is an ancient deposit of aqueous origin, made at a time of submergence in pre-glacial times";† (2) that the Red Gravel was deposited by "an ancient flood of the [Delaware] river of great volume, at a time when it rose 100 or more feet higher than at present," while the bowlders, the absence of life traces, and the altitude of the deposit "point to the melting of a great glacier as the origin of the flood;" and (3) that the brick clay with its contained bowlders represents the closing episode of the same submergence when quiet conditions prevailed;—low temperature being again inferred from the absence of fossils and the presence of ice-borne bowlders.‡ Still more recently the same author pointed out that the Brick Clay and Red Gravel rise to the northward in the Delaware and Lehigh valleys, maintaining a height of 180 to 200 feet above the rivers;§ and, assigning the Yellow Gravel to the newer Pliocene, supposed it to have furnished most of the pebbles of the Red Gravel.‖

In northern Delaware the Philadelphia Brick Clay and Red Gravel of Lewis were found by Chester to merge southward, and he combined them under the name "Delaware Gravels,"¶ and inferred that they represent an epoch of land-submergence and melting glaciers. Subsequently he described the gravels, sands, clays, etc., of the same formation in southern Delaware, identified them with those mentioned by Booth, noted the occurrence of recent marine shells within them, designated the deposit "Estuary Sands,"** and demonstrated from stratigraphic continuity, from petrography, and from paleontology, that it is simply the peripheral extension of that which toward its center is divisible into Brick Clay and Red Gravel.

Merrill has recently described and correlated the formation as found in peninsular New Jersey and on Long Island. He regards the New Jersey deposit as post Pliocene (since it overlies unconformably "all the Mesozoic and known Tertiary beds, and is immediately overlain in turn by the glacial drift where it occurs south of the moraine"),†† and identifies it with the stratified deposits of Gardiner's and Long Islands; and on Long Island he discriminates (1) the Till or Drift proper and (2) the Gravel Drift—identifying the latter with the Yellow Drift or Pre-glacial drift of southern New Jersey‡‡ and noting

* Proc. Acad. Nat. Sci. Philad., vol. xxxii, 1880, 296–7.

† Antiquity and Origin of the Trenton Gravels, appended to "Primitive Industry" by Abbott, 1881, 524.

‡ Ibid., 525, 527.

§ Journal Franklin Institute, xcv, 1883, 369.

‖ Ibid., 371.

¶ This Journal, III, vol. xxvii, 1884, 190–2, 199.

** This Journal, III, vol. xxix, 1885, 40.

†† Official Report Geol. Survey of N. J., 1886, 133.

‡‡ Annals N. Y. Acad. of Sci., iii, 1886, 343.

the unconformable superposition of the former upon it,—enumerates the fossils from the older deposits, and on their testimony refers it to the post-Pliocene and correlates it with the fossiliferous beds of Sancoty Head, and concludes that it was "formed by swift currents which carried along fine and coarse deposits together."*

In 1884 Britton pointed out (1) that the Yellow Gravel of Staten Island and adjacent New Jersey is "a water deposit known to underlie the glacial drift," masses of it being "imbedded in the moraine," and (2) that it reaches altitudes of 200 feet,† while the terraces connected with the terminal moraine rise only 25 or 30 feet above tide.‡. He subsequently followed Cook in designating the formation "Pre-Glacial Drift," noted that it "is distributed along the Atlantic Border, from the coasts of the Southern States northward to the moraine, which it underlies unconformably," mentioned its unconformity to the Miocene, enumerated the fossil plants (mostly recent and local) obtained from it at Bridgeton, N. J., and inferred (1) that it is "later Pliocene or Pleistocene" in age, and (2) that "a considerable amount if not the greater part" of the deposits "may well have come from the erosion of the Cretaceous gravel beds" along the Piedmont margin§—his enumeration and interpretation of the local phenomena being alike eminently satisfactory.

Reviewing the observations of these geologists, it appears (1) that the Rogers brothers, Booth, Conrad, Mather, Lyell, Tuomey, and Desor found a series of stratified sands and clays, containing recent marine shells, rising and expanding from a few feet above tide and a few miles in width in South Carolina, to over 100 feet in altitude, and scores of miles in width in the northern Coastal plain, the fauna being closely related to or identical with that of Gardiner's Island, Sancoty Head, Shirley Point, and other obscure infra-moraine deposits along the New England coast; (2) that these deposits have been shown by W. B. Rogers, Tyson, Kerr and Chester, on the evidence of stratigraphic continuity, unity of structure, and identity of terraces, to extend to the inland margin of the Coastal plain; (3) that Chester has identified the phenomena and in some cases the localities described by Tyson and Booth, and shown that the brick clays and red gravels of the Delaware fall-line are stratigraphically continuous and homogenetic with the fossiliferous marine deposits recognized along the coast by the older geologists; (4) that Lewis has established the identity (in part) of the Philadelphia deposits with the gravels shown

* Annals N. Y. Acad. Sci., iii, 1886, 354–8.
† Proc. Nat. Sci. Assn. of Staten Island, Nov. 8, 1884.
‡ Ibid., April 10, 1886.
§ Trans. N. Y. Acad. Sci., iv, 1884–5 (1887), 26–33.

by H. D. Rogers and Cook, to overspread peninsular New Jersey; (5) that the identity of the New Jersey gravels with the stratified deposits of Gardiner's Island, Long Island, Sancoty Head and Shirley Point has been satisfactorily shown upon paleontologic grounds by Desor, Sanderson Smith, Verrill, Merrill and Britton; and (6) that the series of deposits has been shown by Cook, Merrill, Britton and others, to pass beneath the terminal moraine and its derivatives. In short, colligation of all recorded observations indicates that the entire Coastal plain of the Middle Atlantic slope is occupied by a series of stratified deposits, abounding in bowlders and coarse gravel along the fall-line and bearing recent marine fossils toward the coast, which are overlain unconformably by the terminal moraine in the north.

Reviewing the inferences of the same students as to the genesis and age of the formation it appears (1) that all consider it subaqueous; (2) that the Rogers brothers, Booth, Conrad, Mather, Lyell, Tuomey, Desor, Tyson, Sanderson Smith, Verrill, Cook, Kerr, Chester, Merrill, Britton, and perhaps others hold it to be marine; (3) that W. B. Rogers, Sanderson Smith, Cook, Cope, Kerr, Fontaine, Lewis, Chester, and others believe it was deposited during a period of low temperature; (4) that all refer it, wholly or in part, to the later Tertiary or Quaternary; and (5) that Cook, Merrill and Britton regard it as pre-glacial.

The several observations and inferences are in accord with those recorded above, and are here generalized only to corroborate conclusions reached independently after personal study (chiefly along the inland margin of the formation) in North Carolina, Virginia, the District of Columbia, Maryland, Delaware, Pennsylvania, New Jersey and New York.

Taxonomy.—The local relations.—By stratigraphic position and paleontology the Columbia formation is proved to be newer than any of the recognized Tertiaries of the Middle Atlantic slope, and its fauna is of modern facies. It therefore appears to be Quaternary or Pleistocene in age.

By (1) stratigraphic relations, (2) amount of erosion, and (3) degree of alteration, the formation is proved to be much older than the terminal moraine or the drift sheet whose margin it marks:

1. In the valleys of the Susquehanna and Delaware the terminal moraine is superimposed upon Columbia terraces and in part composed of Columbia materials; and similar relations have been repeatedly observed in New Jersey by Cook, on Staten Island by Britton, and on Long Island by Merrill.

2. A rough quantitative measure of the relative antiquity of the two deposits is found in the erosion they have suffered.

On the upper Susquehanna the post-Columbia and pre-moraine erosion sufficed to excavate a valley from one to two miles wide and 200 feet deep, while the post-moraine erosion has scooped out a valley only a quarter of a mile wide and less than 100 feet in average depth; and similar relations obtain on the upper Delaware. Along the fall-line the post-Columbia erosion is measured by the gorges of the rivers between their falls and their embouchures into estuaries, just as the post-moraine erosion is measured by the gorges of the drift-covered area; and the Potomac and the Niagara are among the most satisfactory of these chronometers. Now since the emergence of the land from the Columbia ocean, the falls of the Potomac have receded through an obdurate terrane from West Washington to Great Falls, a distance of fifteen miles, while the Niagara, under conditions favoring gorge excavations, has receded only seven miles since the last ice-sheet withdrew beyond its latitude; and the contrast is still more striking in scores of other cases. The difference is exemplified by the smaller streams as well as by the larger, and equally by the minor topographic configuration—the hydrography of the Columbia being mature, while that of the superimposed drift is nascent, and the Columbia surfaces being everywhere deeply furrowed and of ancient aspect, while the drift and Champlain surfaces are relatively little touched by time. In short, when post-moraine erosion is measured in yards, post-Columbia erosion must be measured in rods.

3. The moraine is seldom completely oxidized and lixiviated, and its rocks are seldom disintegrated; but where equally exposed the Columbia deposits are profoundly oxidized, lixiviated and ferruginated, and most of its non-siliceous rocks are disintegrated, while the materials are frequently cemented not only by ferruginous but also by siliceous and calcareous matter. The widely diverse degrees of alteration in the two deposits everywhere serves as a criterion by which they may be distinguished.

In brief, the various phenomena of the Columbia formation proves that while it represents an epoch of cold and submergence, it is many times as old as the moraine-fringed drift by which it is unconformably overlain. It is noteworthy, too, that the volume of Columbia deposits is several times greater than the volume of corresponding deposits of the later ice-epoch, indicating that the earlier refrigeration was much the longer; and it is equally noteworthy that the later drift overlaps far upon the earlier aqueo-glacial deposits, indicating that the later cold was the more intense.

The general relations.—A presumably complete sequence of Quaternary deposits and of the events they represent has been

made out in the Great Basin. In 1878 Gilbert described the sediments of the extinct lake Bonneville, recorded the inference that the prevailing arid climate of the Great Basin was interrupted by a period of humid climate during which its mountain-enclosed basins were flooded and the lacustral sediments of Bonneville deposited, and correlated the humid epoch with that of northern glaciation;* and he subsequently pointed out that the humid epoch was brief and apparently "an episode occurring in the later part of a long period of aridity."† In 1878, King called attention to the sediments and chemical precipitates of the ancient lake Lahontan, and, avoiding detailed discussion of the former, conceived the latter phenomena to record (1) flooded and free-drained condition of the lake-basin, (2) shrinking and concentration of the waters and final desiccation of the basin with formation of the precipitate gaylussite, (3) re-flooding of the basin for a long period during which the soluble salts were washed away and the gaylussite changed into thinolite by pseudomorphosis, and (4) partial desiccation producing present conditions. This sequence was regarded as partly coincident with and partly supplementary to that deduced by Gilbert from the Bonneville phenomena; it was inferred that there was "a period of humidity anterior to Gilbert's earliest age of dryness" which was "enormously longer than [the period of humidity] in the second age of desiccation;" and the first of these humid periods was correlated with "the earliest and greatest Glacier period," and the second with "the later Reindeer Glacier period."‡ Gilbert later found evidence in the sediments of the Bonneville basin not only of a long humid period antedating that previously recognized but also of a much longer arid period preceding it, and concluded that the sequence of deposits represents a climatic sequence of "two humid maxima separated by an interval of extreme aridity," the second humid maximum being the more pronounced and the first the longer.§ Still later and after extended investigation, Russell found the sediments and precipitates of lake Lahontan to yield alike a record coincident with that of the Bonneville deposits,‖ save that the intermediate epoch of aridity was lengthened and some minor vicissitudes were introduced. He ascertained from the continuity of shore-lines and other evidence, however, that Lahontan did not overflow during

* Bull. Philos. Soc. of Wash., vol. i, 1874, 84–85; Progress Rep. Geog. and Geol. Surveys West of 100th Merid., for 1872, 1874, 49–50.

† Rep. Geog. and Geol. Surveys West of 100th Merid., vol. iii, Geology, 1875, 96–97.

‡ U. S. Geol. Expl. 40th Parallel, vol. i, Systematic Geology, 1878, 522–4.

§ Second Annual Rep. U. S. Geol. Survey, 1880–1, 1882, 186–200.

‖ Third Ann. Rep. U. S. Geol. Survey, 1881–2, 1883, 221–231; and Monograph U. S. Geol. Survey, vol. x, Geol. History of Lake Lahontan, 1885, 261–263.

either flood stage, and read from the precipitates a record of (1) flooded condition of the basin without free drainage, (2) shrinking and concentration of the waters and precipitation of lithoid tufa (which was overlooked by King), (3) spasmodic reflooding of the basin and successive precipitation of (*a*) the mineral now pseudomorphosed into thinolite and (*b*) dendritic tufa (also overlooked by King), and (4) shrinking of the waters to below present level, followed by a slight re-advance.* This sequence of events is quite inconsistent with that deduced by King, and it thus appears that the coincidence in interpretation of the Lahontan precipitates by King and Russell respectively is no more than curiously fortuitous, and adds nothing to the weight of opinion of either investigator nor to the reliability of the history inferred from other phenomena. But there is a definite sequence of deposits in the Great Basin indicating a definite sequence of events (and the testimony of these deposits is corroborated by the shore-lines and by the precipitate as interpreted by Russell), viz: (1) basal gravels, representing long-continued arid climate; (2) lower lacustral beds; (3) medial gravels; (4) upper lacustral beds; and (5) recent gravels, etc.; and the two lacustral periods are correlated by Gilbert and Russell with two vaguely defined periods of northern glaciation.†

A fairly complete sequence of glacial and aqueo-glacial deposits in Iowa and northern Missouri affords a record of the early Quaternary history of the central Mississippi valley. It was pointed out by the writer in 1878, and again in 1879, that the bipartition of the glacial deposits and the intercalation of a forest bed within them in Iowa indicate two ice invasions separated by a long interglacial period;‡ in 1880 it was made known that the lower glacial deposit (or till) graduates upward into a series of stratified clays and extends much farther southward than the upper, which is associated with or graduates upward into loess;§ in 1882 it was shown that the loess is overlain by a third drift sheet, probably connected with the terminal moraine;‖ and recent investigations have shown that the stratified upper member of the lower till (locally known as "gumbo") not only bears unmistakable structural evidence of aqueous deposition but exhibits in its topographic configuration evidence of submergence of an extended area in Nebraska,

* Op. cit. (2), 236.

† While the lacustral deposits of the Great Basin are regarded as Quaternary by every stratigraphist and physical geologist who has investigated the subject, they have been referred to the Tertiary upon paleontologic grounds by Cope (Am. Naturalist, vol. xxi, 1887, 458–9) and perhaps others.

‡ This Jour., III, vol. xv, 1878, 339–41; Proc. Am. Ass'n for Adv. of Sci., vol. xxvii, 1878, 198–231; Geol. Magazine, N. S., vol. vi, 1879, 353–361, 412–420.

§ Trans. Iowa Hort. Society, 1880.

‖ This Journal, III, vol. xxiv, 1882, 222.

Kansas, Missouri, southern Iowa, Illinois, Indiana and southwestern Ohio, and indeed appears to be a continuation of the Port Hudson formation of the lower Mississippi as defined by Hilgard, thus indicating that during the earlier period of cold the central Mississippi valley was submerged—the far greater antiquity of the earlier till and "gumbo" than of their later homologues (the upper till and loess) being indicated by the intervening forest bed, by the greater disintegration and ferrugination of the older materials and by the far greater degradation beyond the limits of the newer deposits,* while there is much less indication of considerable lapse of time after the deposition of the loess and before the deposition of the superjacent moraine-fringed drift-sheet. So the Iowa-Missouri sequence in historic order is, (1) first glacial drift (basal till) passing upward into waterlaid clays with erratics ("gumbo"), (2) great unconformity and forest bed, (3) second till passing upward into or overlain by loess, (4) inconspicuous unconformity, and (5) third till apparently connected with the terminal moraine.

The glacial phenomena of Northern United States have been elaborately investigated by Chamberlin and found to contain a definite record of the events constituting the glacial history of the continent. His allocation of leading episodes in the historic order is as follows:

Epochs.	Subepochs or episodes.	Attendant or characteristic phenomena.
I. Transition epoch.	Not yet satisfactorily distinguished from the Pliocene.	
II. Earlier glacial epoch.	First subepoch or episode.	Drift sheet with attenuated border; absence or meagerness of coarse ultra-marginal drainage drift.
	Interglacial subepoch or episode of glaciation.	Decomposition, oxidation, ferrugination; vegetal accumulation.
	Second subepoch or episode.	Drift sheet with attenuated border; loess contemporaneous with closing stage.
III. Chief interglacial epoch		Elevation of the Upper Mississippi region 1,000 ± feet. Erosion of old drift, decomposition, oxidation, ferrugination, vegetal accumulations
IV. Later glacial epoch.	First episode or subepoch.	Till sheet bordered by the Kettle or Altamont moraine.
	Episode of deglaciation.	Vegetal deposits
	Second stage or subepoch.	Till sheet bordered by the Gary moraine.
	Episode of deglaciation.	
	Third episode	Till bordered by the Antelope moraine.
	Later stages	Marked by terminal moraines of undetermined importance.

* Trans. St. Louis Academy of Sciences (in press).

Epochs.	Attendant or characteristic phenomena.
V. Champlain epoch	Marine deposition in the Champlain and Saint Lawrence valleys and on Atlantic border; lacustrine deposits about the Great Lakes.
VI. Terrace epoch	Marked by fluvial excavation, notably of the flood plains of second glacial epoch.

When juxtaposed, the Middle Atlantic slope and Great Basin sections are exactly coincident, save (1) that the Champlain clays of the east are unrepresented in the west, and (2) that the duration of the interglacial epoch appears the greater in the east: there is not only the same general succession of events (cold-wet, warm-dry, cold-wet, the whole preceded and followed by warm-dry), but in each case the earlier period of cold and wet was the longer and the cold and wet of the later the more intense; and since the climatic episodes attested by the phenomena in either case were so extreme as to indicate that they were continental in extent, the two series of deposits may safely be correlated. The discrepancies are insignificant, (1) because it is evident that the Champlain epoch of the east must have been represented in the west by simple continuation of preceding conditions, and (2) because the testimony as to the duration of the interglacial epoch is much more complete and satisfactory in the east than in the west.

Difficulty is encountered in juxtaposing the Mississippi Valley section with the foregoing, since Chamberlin's fruitful investigations have convinced him that the longer interglacial epoch occurred posterior to the deposition of the loess and the till with which it is associated; while the writer's observations in Iowa, Missouri, and neighboring states indicate that the a-glacial epoch following the loess period was of limited length and represents only a temporary oscillation in the ice sheet, and that the interglacial period proper occurred anterior to the deposition of the second till and its associated loess. Under either interpretation, however, the section is fairly consistent with those of the Great Basin and Middle Atlantic slope; as interpreted by Chamberlin the short a-glacial epoch of the earlier period of refrigeration might well be regarded as indicating but a temporary oscillation of the ice sheet unaccompanied by appreciable change in altitude or in conditions of aqueo-glacial deposition; while under the writer's interpretation the complexity of the later record is attributable chiefly to its accessibility and to the care with which it has been deciphered, for, despite the greater number of divisions recognized in the later series, it is less important than the earlier as measured either by volume of derived aqueo-glacial deposits or by

contemporaneous erosion. Space would not permit discussion of the data upon which the conflicting opinions rest, even if discussion were desirable; but the difference of view is simply an effect of intellectual perspective which shows to each investigator in exaggerated proportion the phenomena which he has most closely scrutinized, and will disappear with continued observation.

The juxtaposed sections are exhibited in the accompanying table.

It may be pointed out that the succession of deposit in the Mississippi Valley, as interpreted in the third column of the table coincides almost exactly with the sequence recognized by Penck in the German Alps, where the succession in historic order is (1) glacial drift, (2) an enormous accumulation of torrential gravels, now commonly ferruginated, cemented and deeply eroded, (3) a second glacial deposit, (4) a less accumulation of torrential gravels, with alluvium, laminated clays, lignite, etc., and (5) a third glacial deposit, found only at considerable altitudes in the mountains.*

Recapitulation.—In short the Columbia formation underlies and is several times older than the moraine-fringed drift-sheet of northeastern United States; it is apparently the aqueo-glacial margin of a drift-sheet largely concealed or obliterated in the northern Atlantic slope; it appears to be equivalent to the lower lake beds of the Great Basin, to the basal till and "gumbo" of Missouri, to (probably) the Port Hudson of Mississippi, and to (perhaps) the lowest glacial deposits of the Alps; and while the vertebrates of its correlatives suggest that it is Pliocene, both stratigraphy and invertebrate fossils prove that it is Quaternary.

It should be added that the conjoined phenomena of the Middle Atlantic slope and the Mississippi Valley indicate the respective areas of the earlier and later ice sheets: In the east the earlier extended the farther as shown by the superposition of the newer moraine upon the older aqueo-glacial deposits; but whether the earlier glacier formed no moraine, whether there was an earlier moraine perhaps coincident with the drumlin zone passing through central Massachusetts and New York, or whether the earlier drift was obliterated by the later glaciation, remains to be determined. In Iowa, Missouri and southern Illinois, on the other hand, the earlier ice sheet extended fully one hundred miles farther southward than the later, and, having evidently terminated in the waters of the expanded Gulf or of an inland lake, its limit is not marked by a terminal moraine. A hypothetic explanation of this discrepance, based

* Die Vergletscherung der Deutschen Alpen, 1882, 239, Tabelle II, etc.

Conspectus of American Quaternary Phenomena.

Epoch.	Middle Atlantic Slope.	Great Basin.	Mississippi Valley.	
			Interpreted by McGee.	*Interpreted by Chamberlin.*
Second glacial.	Champlain clays.	Upper lake beds.	Lake Agassiz clays.	
	Terminal moraine and upper till.		Terminal moraine and 3d till.	Terminal moraine and 3d till.
			(*Short a-glacial epoch?*)	
			Loess (passing into) 2d till.	
Inter-glacial.	(*Long a-glacial epoch.*)	Media gravels. (*Dry epoch.*)	Forest bed. (*Long a-glacial epoch.*)	(*Long a-glacial epoch.*)
First glacial.	Columbia formation (? passing northward into lower till.)	Lower lake beds.	"Gumbo" (passing into) 1st till.	Loess (passing into) 2d till.
				Forest bed.
				(*Short a-glacial epoch.*)
				1st till.
		Basal gravels.		

on well-known phenomena of the respective regions, is not far to seek: In the east the ice was thick and moved energetically, ploughing up subjacent deposits and scoring subjacent rocks, and quickly reached the line of equilibrium between growth and waste corresponding to given temperature; while in the Mississippi Valley the ice was but a third or a quarter so thick and moved sluggishly, passing over hundreds of square miles without removing the subjacent deposits or touching the subjacent rocks, probably failed to reach its line of equilibrium during the earlier, and certainly fell far short of it during the later and briefer refrigeration. The two ice-boundaries cross somewhere in Ohio.

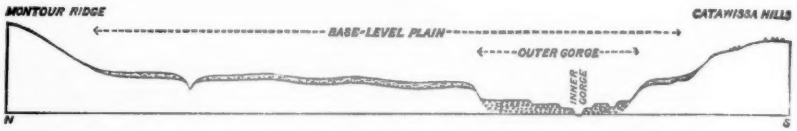
The History Recorded in the Columbia Formation.—The geologic history recorded in the Columbia deposits and terraces and in the erosion and alteration which both have suffered is almost wholly supplementary to that read by most geologists in the later glacial deposits, and multiplies many times the length of the Quaternary as commonly conceived. Collectively the two series of deposits indicate that the Quaternary consisted of two and only two great epochs of cold (the later comprising two or more sub-epochs); that these epochs were separated by an interval three, five, or ten times as long as the post-glacial interval; that the earlier cold endured much the longer; that the earlier cold was the less intense and the resulting ice sheet stopped short (in the Atlantic slope) of the limit reached by the later; that the earlier glaciation was accompanied by much the greater submergence, exceeding 400 feet at the mouth of the Hudson and extending 500 miles southward, while that of the later reached but a tithe of that depth or southing; and that during the long interglacial interval the condition of land and sea was much as at present.

Moreover, as in the Potomac formation, geologic history is recorded not only in the formation itself but in its relation to the floor upon which it rests; and the history read from the deposits is thus materially supplemented.

A remarkable topographic characteristic is displayed by the Piedmont and Appalachian regions in the middle Atlantic slope, which has only been interpreted—or indeed recognized—within the decade. The entire area is but a gently undulating plain, diversified throughout by deeply incised waterways and, in the Appalachian zone, by bosses and ridges of obdurate strata which are narrowed and truncated by erosion but not planed off. The cross-section of the Susquehanna (fig. 1), with its gently undulating plain bounded by mountains and dissected by a steep-bluffed gorge, is representative of the entire Appalachian zone; it is constantly repeated along each principal waterway of that zone, and—save that the bounding mountains are ab-

sent—throughout the Piedmont region; and lines drawn in any direction through the area give ever-varying but harmonious combinations of this profile. During recent years this peculiar configuration has attracted the attention of nearly all geologists who have worked in the area. Stevenson has attributed the broad intermontane plains of the Pennsylvania Appalachians to wave-action during, and their minor irregularities

1.



Cross-Section of Susquehanna Valley between Bloomsburg and Rerwick.

to spasmodic elevation following, a general submergence, and ascribed the incised valleys to the action of the streams now occupying them during a recent epoch of high land;* Kerr attributed the corresponding plains of the Piedmont region in North Carolina to glacial action during a remote epoch;† G. F. Wright ascribes certain of the plains along the western slope of the Appalachians to a temporary ice-dam in the Ohio Valley;‡ I. C. White recently referred the deposits upon these plains, if not the plains themselves, as exhibited along the Appalachian rivers, to submergence probably coeval with northern glaciation;§ but Gilbert has pointed out (orally) that in Virginia and North Carolina, at least, the system of intermontane plains represents an old base-level of erosion. The composite Appalachian profile indeed indicates clearly that at some period of the past the Piedmont-Appalachian area stood low until the rivers, their affluents, the rivulets leading into these, and even the minutest rain-born rills, cut their channels to base level and planed all the rocks except the obdurate quartzites and sandstones to the same level; and that afterward the land was lifted until the waters attacked their channels, cut out the labyrinth of recent gorges, and reduced the valleys, but not the hills, to a new base-level This degradation-record is as definite and reliable as any found within deposits; and while so little is known of the physical relations of the clastic deposits of the Coastal plain (though they have been systematically classified repeatedly upon other bases) that they tell us less than the Piedmont hills of the evolution of the continent,

* Proc. Am. Philos. Soc., vol. xviii, 1879, 315–316.
† This Journal, III, vol. xxi. 1881, 216–19.
‡ Am. Nat., xviii, 1884, 563–7.
§ This Journal, III, xxxiv, 1887, 374–81.

and while it is yet impossible for that reason to correlate the records of land and sea, it will eventually be shown that the broad base-level plain corresponds to an important marine formation somewhere in the Coastal plain series. The unconformity in deposits corresponding to the rise of land closing the base-level period has not been certainly identified, but it seems probable that the deep and broad estuaries of the Coastal plain were then excavated, or at least deepened; and their depth suggests that for a time the land stood higher than now.*

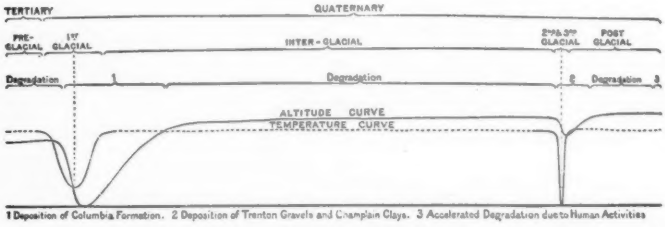
The Columbia formation reposes upon the less elevated portion of the Piedmont-Appalachian base-level plain and within the newer gorges dissecting it, as well as upon the Coastal plain and within its estuaries to considerable depths (generally undetermined but known to exceed 140 feet in Chesapeake Bay). It is evident from the relations of deposit to subterrane in the Piedmont region that the deposition of the formation occurred long posterior to the rise of the land by which the old base-level was disturbed; for despite the high declivity of the stream post-Columbia erosion has not sufficed to lay bare the bottom of the pre-Columbia gorge or to remove more than half or two-thirds of the Columbia deposits in the Susquehanna and Delaware Valleys; and the post-Columbia erosion of the Potomac is measured by a gorge but 15 miles long, half a mile wide, and 75 feet in average depth, while the post-base-level erosion is represented by an outer gorge more than 200 miles long, over a mile in width, and fully 200 feet in average depth, and by corresponding gorges extending to the very sources of all its tributaries. Indeed, when post-glacial erosion is measured in yards and post-Columbia erosion in rods, post-baselevel erosion must be measured in furlongs if not in miles.

So the direct record of the Columbia formation goes back to an era 3, 5, or 10 times as remote as that to which the Quaternary has commonly been carried, while its indirect record extends far into the Tertiary and affords part of the data required for equilibrating Tertiary and Quaternary time—the data from the deposits being yet lacking.

* It should be noted that, as indicated by rapid corrasion on the one hand and the failure of equally rapid deposition to fill the estuaries on the other hand, the Piedmont region is now rising, while the Coastal plain is sinking—the displacement coinciding with the fall line; that this movement has been in progress since the Columbia period at least; and that in consequence the records of continental oscillation found on opposite sides of the fall line are inconsistent. There is evidence, too, that the hydrography of the Coastal Plain, and especially the deflection of the rivers at the fall line, was determined during the Columbia period; and hence that the estuaries were cut not by the rivers which occupy them but by those which more nearly coincide with their courses.

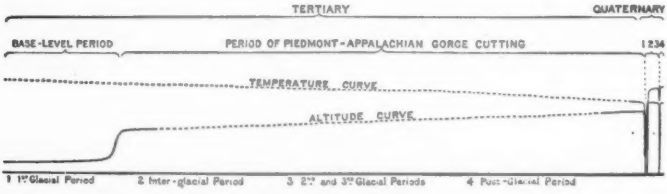
The vicissitudes recorded in the Columbia formation and associated phenomena may be graphically represented as in the accompanying diagrams. It should be pointed out that the earlier part of the record is shadowy, that the quantitative estimates are but roughly approximate, and that the later part of the record is obscured by the fall-line displacement (which cannot be here discussed); yet the graphic interpretation of the

2.



later episodes (fig. 2) is reliable qualitatively, though the relations between these episodes and the more important antecedent vicissitudes is only represented provisionally (fig. 3).

3.



There is a break in geologic history, as commonly interpreted, between the Tertiary and the Quaternary—a hiatus partly natural and partly taxonomic, and exceedingly difficult to close by reason of diverse methods of classification as well as by reason of the dearth of common phenomena. But the formation under consideration is a superficial deposit of known genesis, intimately connected with the other Quaternary deposits of the country; it is at the same time a fossiliferous sedimentary deposit as intimately connected with the Tertiary formations of the middle Atlantic slope as these are connected among themselves; and thus the formation not only covers the natural discontinuity between the Tertiary and Quaternary, but, since it is susceptible of classification with either, closes the taxonomic hiatus as well. So the Columbia formation not only enlarges current conceptions of Quaternary time, and opens a hitherto sealed chapter in geology, but at the same time bridges an important break in geologic history.

ART. XXXIV.—*A Comparison of the Elastic and the Electrical Theories of Light with respect to the Law of Double Refraction and the Dispersion of Colors;* by J. WILLARD GIBBS.

IT is claimed for the electrical* theory of light that it is free from serious difficulties, which beset the explanation of the phenomena of light by the dynamics of elastic solids. Just what these difficulties are, and why they do not occur in the explanation of the same phenomena by the dynamics of electricity, has not perhaps been shown with all the simplicity and generality which might be desired. Such a treatment of the subject is however the more necessary on account of the ever-increasing bulk of the literature on either side, and the confusing multiplicity of the elastic theories. It is the object of this paper to supply this want, so far as respects the propagation of plane waves in transparent and sensibly homogeneous media. The simplicity of this part of the subject renders it appropriate for the first test of any optical theory, while the precision of which the experimental determinations are capable, renders the test extremely rigorous.

It is moreover, as the writer believes, an appropriate time for the discussion proposed, since on one hand the experimental verification of Fresnel's Law has recently been carried to a degree of precision far exceeding anything which we have had before,† and on the other, the discovery of a remarkable theorem relating to the vibrations of a strained solid‡ has given a new impulse to the study of the elastic theory of light.

* The term *electrical* seems the most simple and appropriate to describe that theory of light which makes it consist in electrical motions. The cases in which any distinctively magnetic action is involved in the phenomena of light are so exceptional, that it is difficult to see any sufficient reason why the general theory should be called *electro-magnetic*, unless we are to call all phenomena electro-magnetic which depend on the motions of electricity.

† In the recent experiments of Professor Hastings relating to the index of refraction of the extraordinary ray in Iceland spar for the spectral line D_2 and a wave-normal inclined at about 31° to the optic axis, the difference between the observed and the calculated values was only two or three units in the sixth decimal place (in the seventh significant figure), which was about the probable error of the determinations. See page 60 of this volume.

‡ Sir Wm. Thomson has shown that if an elastic incompressible solid in which the potential energy of any homogeneous strain is proportional to the sum of the squares of the reciprocals of the principal elongations *minus* three is subjected to any homogeneous strain by forces applied to its surface, the transmission of plane waves of distortion, superposed on this homogeneous strain, will follow exactly Fresnel's law (including the direction of displacement), the three principal velocities being proportional to the reciprocals of the principal elongations. It must be a surprise to mathematicians and physicists to learn that a theorem of such simplicity and beauty has been waiting to be discovered in a field which has been so carefully gleaned. See page 116 of the current volume (xxv) of the Philosophical Magazine.

Let us first consider the facts to which a correct theory must conform.

It is generally admitted that the phenomena of light consist in motions (of the type which we call wave-motions) of something which exists both in space void of ponderable matter, and in the spaces between the molecules of bodies, perhaps also in the molecules themselves. The kinematics of these motions is pretty well understood; the question at issue is whether it agrees with the dynamics of elastic solids or with the dynamics of electricity.

In the case of a simple harmonic wave-motion, which alone we need consider, the wave-velocity (V) is the quotient of the wave-length (l) by the period of vibration (p). These quantities can be determined with extreme accuracy. In media which are sensibly homogeneous but not isotropic the wave-velocity V, for any constant value of the period, is a quadratic function of the direction cosines of a certain line, viz: the normal to the so-called "plane of polarization." The physical characteristics of this line have been a matter of dispute. Fresnel considered it to be the direction of displacement. Others have maintained that it is the common perpendicular to the wave-normal and the displacement. Others again would define it as that component of the displacement which is perpendicular to the wave-normal. This of course would differ from Fresnel's view only in case the displacements are not perpendicular to the wave-normal, and would in that case be a necessary modification of his view. Although this dispute has been one of the most celebrated in physics, it seems to be at length substantially settled, most directly by experiments upon the scattering of light by small particles, which seems to show decisively that in isotropic media at least the displacements are normal to the "plane of polarization," and also, with hardly less cogency, by the difficulty of accounting for the intensities of reflected and refracted light on any other supposition.* It should be added that all diversity of opinion on this subject has been confined to those whose theories are based on the dynamics of elastic bodies. Defenders of the electrical theory

* "At the same time, if the above reasoning be valid, the question as to the direction of the vibrations in polarized light is decided in accordance with the view of Fresnel. . . . I confess I cannot see any room for doubt as to the result it leads to. . . I only mean that *if* light, as is generally supposed, consists of transversal vibrations similar to those which take place in an elastic solid, the vibration must be normal to the plane of polarization." Lord Rayleigh "On the Light from the Sky, its Polarization and Color;" *Phil. Mag.* (4), xli (1871), p. 109.

"Green's dynamics of polarization by reflexion, and Stokes' dynamics of the diffraction of polarized light, and Stokes' and Rayleigh's dynamics of the blue sky, all agree in, as it seems to me, irrefragably, demonstrating Fresnel's original conclusion, that in plane polarized light the line of vibration is perpendicular to the plane of polarization." Sir Wm. Thomson, *loc. citat.*

have always placed the electrical displacement at right angles to the "plane of polarization." It will, however, be better to assume this direction of the displacement as probable rather than as absolutely certain, not so much because many are likely to entertain serious doubts on the subject, as in order not to exclude views which have at least a historical interest.

The wave-velocity, then, for any constant period, is a quadratic function of the cosines of a certain direction, which is probably that of the displacement, but in any case determined by the displacement and the wave-normal. The coefficients of this quadratic function are functions of the period of vibration. It is important to notice that these coefficients vary separately, and often quite differently, with the period, and that the case does not at all resemble that of a quadratic function of the direction-cosines multiplied by a quantity depending on the period.

In discussing the dynamics of the subject we may gain something in simplicity by considering a system of stationary waves, such as results from two similar systems of progressive waves moving in opposite directions. In such a system the energy is alternately entirely kinetic and entirely potential. Since the total energy is constant, we may set the average kinetic energy per unit of volume at the moment when there is no potential energy equal to the average potential energy per unit of volume when there is no kinetic energy.* We may call this the equation of energies. It will contain the quantities l and p, and thus furnish an expression for the velocity of either system of progressive waves. We have to see whether the elastic or the electric theory gives the expression most conformed to the facts.

Let us first apply the elastic theory to the case of the so-called vacuum. If we write h for the amplitude measured in the middle between two nodal planes, the velocities of displacement will be as $\frac{h}{p}$, and the kinetic energy will be represented by $A\frac{h^2}{p^2}$, where A is a constant depending on the density of the medium. The potential energy, which consists in distortion of the medium, may be represented by $B\frac{h^2}{l^2}$, where B is a constant depending on the rigidity of the medium. The equation of energies, on the elastic theory, is therefore

$$A\frac{h^2}{p^2} = B\frac{h^2}{l^2} \qquad (1)$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{B}{A}. \qquad (2)$$

* The terms *kinetic energy* and *potential energy* will be used in this paper to denote these average values.

In the electrical theory, the kinetic energy is not determined by the simple formula of ordinary dynamics from the square of the velocity of each element, but is found by integrating the product of the velocities of each pair of elements divided by the distance between them. Very elementary considerations suffice to show that a quantity thus determined when estimated per unit of volume will vary as the square of the wave-length. We may therefore set $Fl^2\frac{h^2}{p^2}$ for the kinetic energy, F being a constant. The potential energy does not consist in distortion of the medium, but depends upon an elastic resistance to the separation of the electricities which constitutes the electrical displacement, and is proportioned to the square of this displacement. The average value of the potential energy per unit of volume will therefore be represented in the electrical theory by Gh^2, where G is a constant, and the equation of energies will be

$$Fl^2\frac{h^2}{p^2} = Gh^2 \tag{3}$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{G}{F}. \tag{4}$$

Both theories give a constant velocity, as is required. But it is instructive to notice the profound difference in the equations of energy from which this result is derived. In the elastic theory the square of the wave-length appears in the potential energy as a divisor; in the electrical theory it appears in the kinetic energy as a factor.

Let us now consider how these equations will be modified by the presence of ponderable matter, in the most general case of transparent and sensibly homogeneous bodies. This subject is rendered much more simple by the fact that the distances between the ponderable molecules are very small compared with a wave-length. Or, what amounts to the same thing, but may present a more distinct picture to the imagination, the wave-length may be regarded as enormously great in comparison with the distances between neighboring molecules. Whatever view we take of the motions which constitute light, we can hardly suppose them (disturbed as they are by the presence of the ponderable molecules) to be in strictness represented by the equations of wave-motion. Yet in a certain sense a wave-motion may and does exist. If, namely, instead of the actual displacement at any point, we consider the average displacement in a space large enough to contain an immense number of molecules, and yet small as measured by a wave-length, such average displacements may be represented by the equations of

wave-motion; and it is only in this sense that any theory of wave-motion can apply to the phenomena of light in transparent bodies. When we speak of displacements, amplitudes, velocities (of displacement), etc., it must therefore be understood in this way.

The actual kinetic energy, on either theory, will evidently be greater than that due to the motion thus averaged or smoothed, and to a degree presumably depending on the direction of the displacement. But since displacement in any direction may be regarded as compounded of displacements in three fixed directions, the additional energy will be a quadratic function of the components of velocity of displacement, or, in other words, a quadratic function of the direction-cosines of the displacement multiplied by the square of the amplitude and divided by the square of the period.* This additional energy may be understood as including any part of the kinetic energy of the wave-motion which may belong to the ponderable particles. The term to be added to the kinetic energy on the electric theory may therefore be written $f_D \frac{h^2}{p^2}$, where f_D is a quadratic function of the direction-cosines of the displacement. The elastic theory requires a term of precisely the same character, but since the term to which it is to be added is of the same general form, the two may be incorporated in a single term of the form $A_D \frac{h^2}{p^2}$, where A_D is a quadratic function of the direction-cosines of the displacement. We must, however, notice that both A_D and f_D are not entirely independent of the period. For the manner in which the flux of the luminiferous medium is distributed among the ponderable molecules will naturally depend somewhat upon the period. The same is true of the degree to which the molecules may be thrown into vibration. But A_D and f_D will be independent of the wave-length, (except so far as this is connected with the period,) because the wave-length is enormously great compared with the size of the molecules and the distances between them.

The potential energy on the elastic theory must be increased by a term of the form $b_D h^2$, where b_D is a quadratic function of the direction-cosines of the displacement. For the ponderable particles must oppose a certain elastic resistance to the displacement of the ether, which in æolotropic bodies will presumably be different in different directions. The potential energy on the electric theory will be represented by a single term of the same form, say $G_D h^2$, where a quadratic function of the direction-cosines of the displacement, G_D, takes the place

* For proof *in extenso* of this proposition, when the motions are supposed electrical, the reader is referred to volume xxiii of this Journal, page 268.

of the constant G, which was sufficient when the ponderable particles were absent. Both G_D and b_D will vary to some extent with the period, like A_D and f_D, and for the same reason.

In regard to that potential energy, which on the elastic theory is independent of the direct action of the ponderable molecules, it has been supposed that in æolotropic bodies the effect of the molecules is such as to produce an æolotropic state in the ether, so that the energy of a distortion varies with its orientation. This part of the potential energy will then be represented by $B_{ND} \frac{h^2}{l^2}$, where B_{ND} is a function of the directions of the wave-normal and the displacement. It may easily be shown that it is a quadratic function both of the direction-cosines of the wave-normal and of those of the displacement. Also, that if the ether in the body when undisturbed is not in a state of stress due to forces at the surface of the body, or if its stress is uniform in all directions, like a hydrostatic pressure, the function B_{ND} must be symmetrical with respect to the two sets of direction-cosines.

The equation of energies for the elastic theory is therefore

$$A_D \frac{h^2}{p^2} = B_{ND} \frac{h^2}{l^2} + b_D h^2, \tag{5}$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{B_{ND}}{A_D - b_D p^2}. \tag{6}$$

The equation of energies for the electrical theory is

$$F l^2 \frac{h^2}{p^2} + f_D \frac{h^2}{p^2} = G_D h^2, \tag{7}$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{G_D}{F} - \frac{f_D}{F p^2}. \tag{8}$$

It is evident at once that the electrical theory gives exactly the form that we want. For any constant period the square of the wave-velocity is a quadratic function of the direction-cosines of the displacement. When the period varies, this function varies, the different coefficients in the function varying separately, because G_D and f_D will not in general be similar functions.* If we consider a constant direction of displacement while the period varies, G_D and f_D will only vary so far as the type of the motion varies, *i. e.*, so far as the manner in which the flux distributes itself among the ponderable mole-

* But G_D, f_D, and V^2, considered as functions of the direction of displacement, are all subject to any law of symmetry which may belong to the structure of the body considered. The resulting optical characteristics of the different crystallographic systems are given in volume xxiii of this Journal, page 273.

cules and intermolecular spaces, and the extent to which the molecules take part in the motion are changed. There are cases in which these vary rapidly with the period, viz: cases of selection absorption and abnormal dispersion. But we may fairly expect that there will be many cases in which the character of the motion in these respects will not vary much with the period. $\frac{G_D}{F}$ and $\frac{f_D}{F}$ will then be sensibly constant and we have an approximate expression for the general law of dispersion, which agrees remarkably well with experiment.*

If we now return to the equation of energies obtained from the elastic theory, we see at once that it does not suggest any such relation as experiment has indicated, either between the wave-velocity and the direction of displacement, or between the wave-velocity and the period. It remains to be seen whether it can be brought to agree with experiment by any hypotheses not too violent.

In order that V^2 may be a quadratic function of any set of direction-cosines, it is necessary that A_D and b_D shall be independent of the direction of the displacement, in other words, in the case of a crystal like Iceland spar, that the direct action of the ponderable molecules upon the ether, shall affect both the kinetic and the potential energy in the same way, whether the displacement take place in the direction of the optic axis or at right angles to it. This is contrary to everything which we should expect. If, nevertheless, we make this supposition, it remains to consider B_{ND}. This must be a quadratic function of a certain direction, which is almost certainly that of the displacement. If the medium is free from external stress (other than hydrostatic), B_{ND}, as we have seen, is symmetrical with respect to the wave-normal and the direction of displacement, and a quadratic function of the direction-cosines of each. The only single direction of which it can be a function is the common perpendicular to these two directions. If the wave-normal and the displacement are perpendicular, the direction-cosines of the common perpendicular to both will be linear functions of the direction-cosines of each, and a quadratic function of the direction-cosines of the common perpendicular will be a quadratic function of the direction-cosines of each. We may thus reconcile the theory with the law of double refraction, in a certain sense, by supposing that A_D and b_D are independent of the direction of displacement, and that B_{ND} and therefore V^2 is a quadratic function of the direction-cosines of the common perpendicular to the wave-normal and the dis-

* This will appear most distinctly if we consider that V divided by the velocity of light *in vacuo* gives the reciprocal of the index of refraction, and p multiplied by the same quantity gives the wave-length *in vacuo*.

placement. But this supposition, besides its intrinsic improbability so far as A_D and b_D are concerned, involves a direction of the displacement which is certainly or almost certainly wrong.

We are thus driven to suppose that the undisturbed medium is in a state of stress, which, moreover, is not a simple hydraulic stress. In this case, by attributing certain definite physical properties to the medium, we may make the function B_{ND} become independent of the direction of the wave-normal, and reduce to a quadratic function of the direction-cosines of the displacement.* This entirely satisfies Fresnel's Law, including the direction of displacement, if we can suppose A_D and b_D independent of the direction of displacement. But this supposition, in any case difficult for aeolotropic bodies, seems quite irreconcilable with that of a permanent (not hydrostatic) stress.

For this stress can only be kept up by the action of the ponderable molecules, and by a sort of action which hinders the passage of the ether past the molecules. Now the phenomena of reflection and refraction would be very different from what they are, if the optical homogeneity of a crystal did not extend up very close to the surface. This implies that the stress is produced by the ponderable particles in a very thin lamina at the surface of the crystal, much less in thickness, it would seem probable, than a wave-length of yellow light. And this again implies that the power of the ponderable particles to pin down the ether, as it were, to a particular position is very great, and that the term in the energy relating to the motion of the ether relative to the ponderable particles is very important. This is the term containing the factor b_D, which it is difficult to suppose independent of the direction of displacement because the dimensions and arrangement of the particles are different in different directions. But our present hypothesis has brought in a new reason for supposing b_D to depend on the direction of displacement, viz: on account of the stress of the medium. A general displacement of the medium midway between two nodal planes, when it is restrained at innumerable points by the ponderable particles, will produce special distortions due to these particles. The nature of these distortions is wholly determined by the direction of displacement, and is hard to conceive of any reason why the energy of these distortions should not vary with the direction of displacement, like the energy of the general distortion of the wave-motion, which is partly determined by the displacement and partly by the wave-normal.†

* See note on page 467.

† The reader may perhaps ask, how the above reasoning is to be reconciled with the fact that the law of double refraction has been so often deduced from the elastic theory. The troublesome terms are b_D and the variable part of A_D,

But the difficulties of the elastic theory do not end with the law of double refraction, although they are there more conspicuous on account of the definite and simple law by which they can be judged. It does not easily appear how the equation of energies can be made to give anything like the proper law of the dispersion of colors. Since for given directions of the wave-normal and displacement, or in an isotropic body, B_{ND} is constant, and also A_D and b_D, except so far as the type of the vibration varies, the formula requires that the square of the index of refraction (which is inversely as V^2) should be equal to a constant diminished by a term proportional to the square of the period, except so far as this law is modified by a variation of the type of vibration. But experiment shows nothing like this law. Now, the variation in the type of vibration is sometimes very important,—it plays the leading rôle in the phenomena of selection absorption and abnormal dispersion,—but this is certainly not always the case. It seems hardly possible to suppose that the type of vibration is always so variable as entirely to mask the law which is indicated by the formula when A_D and b_D (with B_{ND}) are regarded as constant. This is especially evident when we consider that the effect on the wave-velocity of a small variation in the type of vibration will be a small quantity of the second order.*

The phenomena of dispersion, therefore, corroborate the conclusion which seemed to follow inevitably from the law of double refraction alone.

Art. XLI.—*Notes on the Surface Geology of Southern Oregon;* by Henry J. Biddle.

During the Summer of 1887, the writer had occasion to visit that portion of southern Oregon which lies within the area of interior drainage, and forms the northwestern part of the Great Basin. In the intervals of other work, some notes on the surface geology of the region were made, which, though necessarily fragmentary and incomplete, may yet be of suffi-

which express the direct action of the ponderable molecules on the ether. So far as the (quite limited) reading and recollection of the present writer extend, those who have sought to derive the law of double refraction from the theory of elastic solids have generally either neglected this direct action—a neglect to which Professor Stokes calls attention more than once in his celebrated "Report on Double Refraction" (Brit. Assoc., 1862, pp. 264, 268,)—or taking account of this action they have made shipwreck upon a law different from Fresnel's and contradicted by experiment.

* See volume xxiii of this Journal, pp. 271, 272, or Lord Rayleigh's "Theory of Sound," vol. i, p. 84.

cient interest to justify their publication. This region was reconnoitered by Mr. I. C. Russell in 1881 and 1882; and to his description* reference must be had for a complete account of its topography and surface geology. These notes are merely intended to supplement some of the observations of that writer, and to call attention to a few points not previously noted. A portion of northern California, which has the same topographical features and geological structure as southern Oregon, is included in the following observations.

The first region to be considered is Warner Valley. This is a long, narrow valley, bounded on both sides by fault scarps of grand proportions, and extending in a nearly north and south direction. Its southern end is close to the point where the dividing line between California and Nevada meets the southern boundary of Oregon. This valley, as already noted by Russell,† was occupied by a Quaternary lake, which never overflowed; and in its lowest portions are, at present, a chain of shallow lakes, and marshes. These lakes all drain, during the wet season, into the northernmost lake; and are consequently, with the exception of the latter, nearly or quite fresh. The northernmost lake, on the contrary, is alkaline and brackish. A sample of this body of water, collected in September, was found to contain about four grams of solid matter to the liter. Qualitative analysis showed the presence of sodium, magnesium, traces of calcium and potassium, chlorine, sulphuric and carbonic acids,—the chief constituent being common salt. The salts contained in this lake do not, however, represent the total amount left by the evaporation of the ancient lake. On the east side of the valley, near its northern end, is a group of ponds and marshes, the waters of which are highly concentrated salt solutions. When dried by the heat of summer they leave crusts of various salts. The common salt from these ponds, though somewhat impure from the admixture of sulphates, has become of importance to the country round about; and several hundred tons are collected annually for salting sheep and cattle. As the supply is renewed every year, it is reasonable to infer that the salt is derived from the sediments in the bed of the ancient lake, which absorbed most of the salts left upon its desiccation. In addition to sodium chloride, the waters of these ponds contain a great quantity of sodium and magnesium sulphates, and a trace of borax. In the mud beneath the ponds are crusts of sodium sulphate, and nodules, up to three inches in diameter, of a mineral which has the composition of Ulexite, a borate of soda and lime.

* Fourth Annual Report of the U. S. Geological Survey. A Geological Reconnaissance in Southern Oregon, by I. C. Russell.

† Loc. cit., p. 459.

Next to be considered is the region embraced in the valleys of Summer, Abert and Goose lakes. While each of these lakes has its own system of drainage, all being at present without outlet, yet from the fact that they are only separated by divides of slight elevation in comparison to the surrounding mountains, they can conveniently be grouped together. Another reason for considering them together is, as will be shown, the probability that they once belonged to the same drainage system.

The valleys of Summer and Abert lakes, together with the low region between them, now occupied by the Chewaucan Marsh, were filled, during the Quaternary period, by a lake of considerable size. The boundaries of this ancient lake have been mapped by Russell.* In the lowest portions of its bed are the existing lakes, Summer and Abert. They resemble each other in many respects, and are both highly charged with various salts in solution; but the waters of Abert lake contain about twice as great a percentage of total solids as those of Summer lake. Qualitatively the salts in both lakes are the same. A sample of the water of Abert lake was collected on the 18th of September, 1887, off a rocky point near the middle of the west shore. It was taken one foot below the surface and about ten yards from land; the depth of the water being five feet, and temperature 15° C. The following analysis of this sample by Dr. T. M. Chatard, of the U. S. Geological Survey, is published by permission.

Specific Gravity 1·03117 at 19·8°.
In 25 c.c. = 25·77295 grams.

	A.	B.	Average.	Grams in a liter.	Percentage of total solids.
SiO_2	0·0063	0·0053	0·00580	0·232	0·59
K	0·0133	0·0136	0·01345	0·538	1·37
Na	0·3674	0·3671	0·36725	14·690	37·51
SO_3	0·0148	0·0146	0·01470	0·588	1·50
O	0·0030	0·0029	0·00295	0·118	0·30
Cl	0·3365	0·3366	0·33655	13·462	34·37
CO_2	0·1755	0·1757	0·17560	7·024	17·93
O	0·0615	0·0616	0·06155	2·462	6·28
H in bicarbonates				0·058	0·15
			Grams	39·172	100·00

Hypothetical Composition.

	Grams in a liter.	Percentage of total solids.
SiO_2	0·232	0·59
KCl	1·027	2·62
NaCl	21·380	54·58
Na_2SO_4	1·050	2·68
Na_2CO_3	10·611	27·09
$NaHCO_3$	4·872	12·44
	39·172	100·00

* Loc. cit., map 83.

An analysis, quoted by Russell,* of a previous sample from this lake showed a remarkably high percentage of potassium salts. The above analysis, on the contrary, shows a less proportion of potassium than reported in the waters of Mono Lake, Owen's Lake, or Great Salt Lake.† The writer is at a loss to account for the wide variation between these analyses. Both show a very low percentage of sulphates, far less than in the other lakes of the Great Basin mentioned.

The occurrence of tufa deposits in the bed of the ancient lake alluded to has not previously been reported. In the low region between the existing water bodies fragments of a calcareous crust, usually less than one-half inch in thickness, together with concretions of small size, lie sparsely scattered on the surface. Near the shore of Summer Lake the sands are cemented into a crust from one-eighth to one-half inch thick, which appears to be of very recent formation, and might have been formed when the lake stood but a few feet higher than at present. These facts merely go to show that the history of this ancient water body was, in a small way, similar to that of the larger inclosed lakes of the Great Basin.

Goose Lake Valley is south of the region just described; it extends nearly north and south, and lies partly in Oregon, partly in California. At its northern end it is connected by a low pass with the southern end of the depression in which Abert Lake lies. This valley was occupied by an ancient lake, the boundaries of which have never been mapped. It had about twice the area of the present Goose Lake, and a depth approaching 300 feet. As the hillsides in this region are in part clothed with forest, the ancient beach lines do not form as noticeable a feature as in the arid valleys north and east of it. Near the town of Lakeview, however, is a conspicuous and well defined terrace, showing the surface level of the ancient lake. This terrace is deeply cut into the spurs of the mountain side, having in places a width of several hundred feet. It has two minor benches, at an elevation respectively of 250 and 280 feet above the floor of the valley.‡ These benches are in places level, but usually have a lakeward slope of about 5°, and are separated by a somewhat steeper slope. On the side toward the valley the slope increases abruptly, reaching 25°, while toward the mountain there is a gradual increase of slope until the normal inclination of the mountain side is attained. There is no cliff separating the terrace from the mountain slope. The surface of the two benches is often covered with

* Loc. cit., p. 454.

† For a comparison of the analyses of these, and other inclosed lakes, see Monograph XI, U. S. G. S Geological History of Lake Lahontan, by I. C. Russell, Table C.

‡ These measurements are by aneroid.

rounded and subangular pebbles, though in places these occur but sparingly. In the northernmost part of the ancient lake basin is a row of round topped hills, stretching five or six miles from the mountain border on the west and nearly spanning the valley. These hills rise fully 200 feet above the level plain at their feet, and are covered from base to summit with water-worn gravel. While it is evident that these vast accumulations of gravel were formed by the waves and currents of the ancient lake, yet it is not clear to the writer how they obtained their present form. The supposition that an ancient, and once continuous, gravel bar or embankment has been cut to its base, at several points, by lines of recent drainage, partially explains the peculiar topography.

Passing to the extreme northern end of the valley, the pass leading to Abert Lake is found to be lower than the ancient beach lines and gravel accumulations alluded to. At the divide in this pass, and thirty or forty feet above the lowest point, a considerable quantity of water-worn pebbles may be seen on the hillside. Taking these facts into consideration, it is impossible to avoid the conclusion that when Goose Lake Valley was filled to its highest beach line its waters overflowed this pass, and communicated with the lake north of it. But the ancient shore lines cannot be traced from one valley to the other, owing chiefly to the broken nature of the country; and the evidence of this fact is not as clear as could be wished. When the pass alluded to was overflowed it must have formed a narrow strait, of no great depth, connecting two large bodies of water. Goose Lake found an outlet at its southern end, and hence this strait might have furnished an outlet to the ancient lake north of it, by which it could discharge its surplus water. This question will be referred to later on.

Although Goose Lake does not at present overflow, yet a rise of but a few feet would cause its waters to discharge southward into the North Fork of Pit River, and thence into the Sacramento. This is reported by Russell* to have taken place as recently as 1869, and again for a short period in 1881. When the lake stood at the level of its highest beach line, it is evident that the valley of Pit River was yet to be cut; and the depth to which the waves eroded the mountain side shows that for a long time the lake maintained a nearly constant level, and nothing was accomplished toward deepening the channel of discharge. But when the cutting down of this channel commenced it must have been comparatively quickly accomplished, as is shown by the absence of beach lines at lower levels than those mentioned. Perhaps other lakes, on the lower courses of Pit River, had first to be drained; and not until this had been

* Reconnaissance in Southern Oregon, p. 456.

effected did the outflowing waters have sufficient fall to carry on the work of erosion. Of course the hypothesis is admissible that the lake had at first no outlet, and was in course of time tapped by a stream belonging to another drainage system, cutting back its channel across the divide. Had the climatic conditions of a former period continued to the present day, the work of deepening the channel of outflow would most likely have gone so far as to completely drain the valley, and leave only marshes and meadows in place of the present water body. But before this task was accomplished the supply of water was so diminished that the lake disposed of it all by evaporation, and none escaped to continue the cutting down of the outlet.

The question naturally occurs, did the great lake north of this also cut down its outlet? But as there is no evidence of erosion by running water in the pass mentioned, which was once a strait connecting the two water bodies, the question must be answered in the negative. Naturally nothing could be accomplished toward deepening this channel until the level of Goose Lake had been lowered to about the level of the bottom of the strait. As has been shown, a long period must have elapsed before this was the case; and if at the end of this period, the humid climate of Quaternary times was giving place to the later aridity, the lake would have no surplus waters to discharge. Indeed, we know that many of the lakes of this region never overflowed, even during the periods of greatest humidity; and with a large surface for evaporation and comparatively small tributary drainage area, the lake in question may never have had any surplus water to dispose of.

The waters of Goose Lake do not appear ever to have deposited tufa. The existing lake is very nearly fresh, containing less than one thousandth of solids in solution, and is inhabited by fish. Unfortunately there are no good exposures in the bed of the ancient lake, and the character of its sediments is unknown.

South of the region just described is a basin, drained by Pit River, known as Warm Spring Valley. Although the district has not been visited by the writer, yet from the topography it seems safe to assume that this valley has also contained an ancient lake which was drained by the cutting down of its outlet. When the surface geology of this region shall be systematically studied, traces of many extinct lakes hitherto unnoticed will no doubt be found.

The next region to which these notes have reference is Surprise Valley, lying in the northeast corner of California. This valley contained a Quaternary lake which never overflowed. Its modern representatives are three shallow lakes occupying the deepest portions of the basin, and known respectively as

Upper, Middle, and Lower, Alkali Lake. During the summer these lakes often dry up completely, leaving broad, level stretches of fine-grained yellow mud. When visited by the writer in September, 1887, the middle lake was quite dry, the others nearly so. The water in the upper or northernmost lake was found to be a strong saline and alkaline solution. It contained about 45 grams of solids to the liter, mostly sodium chloride. By digging into the mud near the center of the middle lake the following section was obtained, beginning at the surface: 4 feet of yellow fine-grained mud, 3 inches of fine white volcanic dust, 3 feet of black mud smelling of hydrogen sulphide. At the depth of seven feet the hole in the lake bed filled with brine, which was found to contain about 38 grams of salts to the liter—mostly sodium chloride, with some carbonate and sulphate. This shows what has become of the salts which must have accumulated during a long period in the basin of the ancient lake. But a fraction of the total amount exists in the shallow lakes of to-day; the greater portion must be looked for in the brine saturating the mud beneath them to an unknown depth.

The existence of a stratum of volcanic dust in this valley is a fact of interest hitherto unreported. Similar strata occur among the sediments of the ancient Lake Lahontan, as reported by I. C. Russell.* That writer regards them as derived from the craters about Mono Lake, Cal., and has observed such material up to 200 miles from the supposed place of eruption. The middle of Surprise Valley is about 250 miles from Mono Lake, but less than half that distance from the volcanic region of Mt. Shasta and Lassen's Peak. Further observations are necessary to determine from which direction the volcanic dust of Surprise Valley was derived. There seems to be in this occurrence evidence of very recent volcanic activity. The time in which a narrow lake, receiving annual supplies of sediment-laden water and æolian dust, has deposited four feet of mud in its bed, can hardly be very great.

The region next to be considered lies on the border of the Great Basin, and possesses the same topographical features as the valleys previously mentioned; but now belongs partly to the hydrographical area of the Pacific. This is the region embraced in the valleys of Rhett Lake, and the Upper and Lower Klamath lakes. It lies partly in Oregon, partly in California. The whole may be regarded as one valley, formed by a complicated system of faults, with a nearly level floor on which the lakes mentioned lie. Two of these lakes, the Upper and Lower Klamath, discharge their waters by way of the Klamath River into the Pacific, while Rhett Lake on the other hand

* Lake Lahontan, p. 146.

has no outlet. But a slight rise in the water of the latter would cause it also to become tributary to the Klamath River, as there is no high ground between.

There seems to be no doubt that this system of valleys was occupied by a large lake, which has been nearly drained by the cutting down of its outlet. The writer was, however, unable to detect any beach lines which would show the extent and depth of the ancient lake. It is possible that it was so shallow that its waves had little force, and left no trace of their action. But fortunately the sediments in its bed are in places exposed. Lost River, an affluent of Rhett Lake, has cut its channel into the floor of the valley to the depth in places of 40 feet. A bluff on the south side of this stream, about 10 miles southeast of the town of Linkville, shows a good section of the lake beds. They are seen to consist chiefly of a light gray, fine-grained earth, which at first sight might be taken for chalk. Interstratified with this are occasional layers, but a few inches thick, of sand and pebbles with a ferruginous cement.

When the earth forming the mass of these deposits is examined under the microscope it is seen to consist wholly of infusorial remains. It is homogeneous and of exceedingly fine texture; compact enough to form steep bluffs, but in small lumps easily crushed between the fingers. It is so light as to float for a moment in water, and adheres slightly to the tongue. The strata dip about northeast, or toward the mountains, at an angle of 12°. This dip may be due to deposition in inclined layers; but in that case one would expect to find the slope in the opposite direction, or toward the middle of the valley. Without more extended observations it can not, however, be maintained that a tilting of these beds has taken place. At the top of the bluff they are seen to be overlaid by a horizontal layer of gravel, containing rounded lumps of the infusorial earth.

A system of joints extends through the beds in a plane about parallel to the strike and at right angles to the dip. For a considerable distance the channel of Lost River lies in the infusorial beds, and wherever exposed the jointing is a noticeable feature. The same material may be traced for about 10 miles along the northeast edge of the basin in which Linkville lies; the total extent of the deposit is yet to be determined.

Mr. J. S. Diller, of the U. S. Geological Survey, has called attention* to similar infusorial deposits on Pit River and the lower courses of the Klamath. They occur, as in this case, in the beds of extinct lakes. The writer desires to express his obligation to Mr. Russell, of the U. S. Geological Survey, for his kind assistance and advice; to Dr. Chatard, of the Survey, for his analysis quoted; and to Mr. Merrill, of the U. S. National Museum, for the microscopic determination of volcanic dust.

* U. S. G. S. Mineral Resources, 1886, p. 588.

Art. XLII.—*Some Nickel Ores from Oregon;* by F. W. Clarke.

In or about the year 1881, extensive deposits of nickel silicates were discovered in Douglas County, Oregon. In appearance, the ores are identical with the so-called "garnierite" and "noumeaite" of New Caledonia, and many specimens bearing those names have found their way into collections of minerals. At present, the deposits at Riddle, Oregon, are being worked by the Oregon Nickel Company, and through the kindness of Mr. Will Q. Brown, an admirable series of the ores was recently sent to the United States Geological Survey for investigation. According to Mr. Brown the deposits all lie at or near the surface, in beds from four to thirty feet thick. Mining is carried on through open cuts or quarries, and no second bed has ever been found underlying the first.

The specimens at my disposal represent a wide range of appearances. They include samples of the country rock and of the associated chromite, and the nickel silicates themselves vary much in color and texture. The finest specimens are bright apple green, and quite compact, and from this they range through duller shades into masses of distinctly earthy texture. Most of them are intermixed with oxides of iron and with quartz, and even the purest mineral, like the garnierite of New Caledonia, is seamed with thin sheets of chalcedony. All of the nickel bearing samples are much decomposed; and one particularly beautiful specimen is distinctly a conglomerate or breccia, having nodules of the green ore imbedded in it side by side with pebbles and fragments of other material. Like all the nickel silicates which have been so far observed in nature, these ores are unmistakably products of alteration; and the problem of their genesis is somewhat interesting. For comparison with them I had a suite of the New Caledonia minerals, received from Professor Liversidge, and a large series of the genthites from Webster, N. C., collected last summer by Mr. W. S. Yeates. All three localities have much in common, and the three sets of specimens point clearly to one conclusion, which will be stated farther on after the evidence for it has been presented.

In composition, the nickel silicates from any locality vary widely; for the earthy nature of the material renders it impossible to secure anything like a homogeneous substance for analysis. The purest specimen of the Riddle ore was dark apple green, compact, and amorphous; but so permeated with films of silica that a definite mineral could not be isolated. With the best material obtainable I secured the following re-

sults; which I give side by side with two published analyses by Hood,* in order to show the variations.

	Clarke.	Hood.	Hood.
Loss at 110° C.	8·87	6·63	7·00
Loss on ignition	6·99		
$Al_2O_3 + Fe_2O_3$	1·18	1·38	1·33
SiO_2	44·73	48·21	40·55
MgO	10·56	19·90	21·70
NiO	27·57	23·88	29·66
	99·90	100·00	100·24

Neither lime, sulphates, chromium, nor cobalt could be detected. Like the New Caledonia garnierite, the fragments of this silicate fell to pieces when immersed in water.

Of the New Caledonia silicates many analyses have been published, notably by Liversidge and Leibius, Typke, Damour, Garnier and Ulrich, and they vary between widely separated extremes. Not only are there the variations due to mutual replacements of nickel and magnesia, with a range in the percentage of NiO from 0·24 to 45·15 per cent, but there are also great differences in silica and in hydration. It is therefore impossible to say whether we have to deal with one nickel salt, varying only in its impurities, or with several compounds: although the general similarity of the material from different localities renders the former supposition the more probable. According to Ulrich† the noumeaite and garnierite consist of a soapstone-like base, with a hydroxide or silicate of nickel distributed through it in veins and patches; while Des Cloizeaux‡ regards noumeaite as a magnesian hydrosilicate impregnated with nickel oxide. The latter view, however, is hardly probable, especially when we consider the origin of the minerals; and Typke§ has cited evidence against it. The prevalent opinion, that we have to deal with one or more definite hydrosilicates of nickel, is best sustained by careful comparative study of the specimens, even though the salts may not be obtained pure or positively formulated. The reciprocal variation of nickel and magnesia in more than twenty published analyses, excludes from further consideration the idea that the nickel is present to any great extent as hydroxide. For temporary convenience we may use the well-recognized name "genthite" generically, and apply it to all the nickel silicates from the above-named localities.

Of the "country rock" surrounding the Oregon beds one large, clean, fresh specimen was received. This was subjected

* Mineral Resources of the United States for 1883.
† This Journal, III, xi, 235. ‡ Bull. Soc. Min., i, 29. § Chem. News, xxxiv, 193.

to analysis, and also, through the kindness of Mr. J. S. Diller, to careful microscopic study. The olivine separated from it by Mr. Diller was analyzed as well, although the material was not absolutely free from enstatite and chromite, and both analyses are here presented together.

	Rock.	Olivine.
Ignition	4·41	·57
SiO_2	41·43	42·81
Al_2O_3	·04	....
Cr_2O_3	·76	·79
Fe_2O_3	2·52	2·61
FeO	6·25	7·20
NiO	·10	·26
MnO	none	none
CaO	·55	none
MgO	43·74	45·12
	99·80	99·36

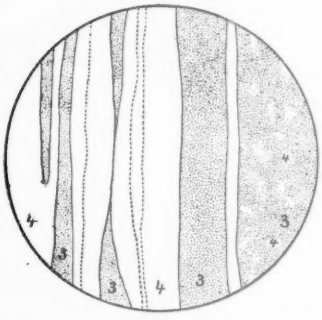
It will at once be seen from these data that the rock contains nickel, and that the olivine separated from it contains even a larger proportion. This fact suggests a probable source of derivation for the nickel in the altered beds of ore, and this view is maintained by the microscopic investigation. Concerning the latter, Mr. Diller reports as follows, discussing both the rock and the genthite.

"The high specific gravity and dark yellowish green color of the country rock with which the genthite is associated at Riddle, Oregon, at once suggests that it belongs to the peridotites, and such it is proved to be by investigation. It is a holocrystalline granular rock, composed essentially of olivine and enstatite with a small percentage of accessory chromite and magnetite. The olivine predominates, so that the enstatite forms less than one-third of the mass. Both of these minerals are clear and colorless, but may be readily distinguished by their cleavage and optical properties. They are allotriomorphic, i. e. not bounded by crystallographic planes, and do not contain prominent inclusions, excepting a few grains of chromite and magnetite and fine ferritic dust. Notwithstanding the comparatively fresh condition of the rock, to which, according to Wadsworth, the name Saxonite may be applied, it is completely permeated by a multitude of cracks filled with serpentine resulting from alteration. Quartz also results from the metasomatic changes in the saxonite, and wherever the genthite occurs it is always associated with either quartz or serpentine."

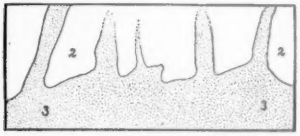
"The genthite from Oregon varies in color from green to pale apple or yellowish green in reflected light, and is compact

with a faint suggestion of fine granular structure. Generally it is dull, but where most compact and traversed by a series of minute fissures or seams of quartz it has a decidedly waxy luster. Under the microscope it usually appears to be an aggregation of irregular grains which have in transmitted light a pale yellowish green to coffee-brown color, and a peculiarly clouded waxy aspect. Where the grains are very thin the genthite may be said to be transparent and isotropic, but the majority of them are only translucent. In the narrow seam of genthite lying between seams of quartz the former is indistinctly fibrous and feebly double-refracting; but its system of crystallization could not be definitely determined. In small veins it is free from grains of other minerals, but elsewhere it is very intimately commingled with quartz. The relation of the two minerals is shown in the accompanying figure 1, in which the shaded portions (3) are genthite, and the clear one (4) are quartz. The commingling of the two minerals is so intimate as to make it evident that both were deposited from solution in circulating waters. Veinlets of quartz are frequently found cutting across those of genthite, and in general it appears to be true that the latter mineral was laid down first, although it is probable that both were precipitated at about the same time. Although the purest genthite is to be found with quartz, the mineral is more commonly associated with serpentine; and this relation is a most important one in its genetic significance. The accompanying figure 2 represents the edge of one of the larger veins of genthite (3), with numerous veinlets or fissures extending out into the serpentine (2). The tributaries are abundant on both sides of the vein. Figure 3 shows a vein of genthite (3) in the serpentine (2), which envelopes small masses of residuary oxide of iron (1), left by the decomposing olivine. The area represented is only 0·64 of a millimeter in diameter and contains no olivine; but less than half a millimeter from the boundary of the vein much olivine still remains, although deeply coated with oxide of iron and serpentine. The branching streamlets from the vein

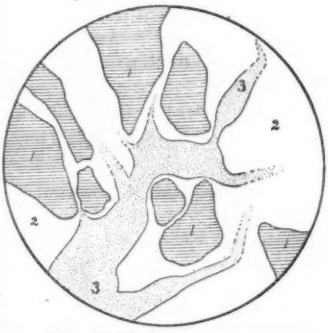
1.



2.



of genthite, together with the manner in which the arms gradually fade away into the serpentine at once suggests the source from which the genthite has been drawn. The genthite and serpentine are thoroughly intermingled, but the former is generally present in such small quantities as to be overlooked unless it is the object of special research. It occurs in the serpentine directly connected with the grains of olivine from which the serpentine has been derived, and there is every reason to believe that the genthite came from the same source."



In order to secure completer confirmation of the idea that the nickel of the greater silicate deposits is derived from the alteration of nickeliferous olivine, Mr. Diller at my request, also examined specimens from Webster, N. C., and from New Caledonia. Concerning the Webster genthite Mr. Diller reports that "it is almost identical with that from Oregon, excepting that it is not so thoroughly intermingled with quartz. The relation of the genthite to the serpentine and the olivine at the Webster locality is exactly the same as at Riddle. The rock at Webster differs slightly from that at Riddle in containing a smaller proportion of enstatite, and belongs to the peridotites to which the name 'dunyte' has been applied" He also finds the New Caledonia mineral to be identical with genthite in its physical properties, and says—"Under the microscope it varies from pale yellowish green to light coffee-brown, and is either completely isotropic or exhibits only faint aggregate polarization. Like the genthite of Oregon it is deposited in layers and cavities thoroughly intermingled with quartz, and in the same thin section may be seen serpentine with traces of olivine and enstatite so disposed as to clearly indicate that the serpentine, noumeaite, and other secondary products have resulted from the alteration of peridotite." This observation confirms the earlier one of Des Cloizeaux (l. c.), who stated that the noumeaite was imbedded in a serpentine rock which appeared to be derived from olivine, and which contained crystals of the latter mineral plentifully disseminated through it. A similar suggestion is made by Mr. H. J. Biddle,* who regards the nickel of the Webster deposits as an original constituent of the olivine rock, and cites an experiment of Mr. G. B. Hanna, who found 0·15 per cent of nickel oxide in a chrysolite from Waynesville, N. C.

* Mineral Resources of the U. S., 1886.

So far, the case appears to be clearly and conclusively settled as to the origin of the nickel silicates under discussion. Nickel is almost always present in small quantities in olivines, and T. Sterry Hunt, in reporting genthite from Michipicoten Island* calls attention to the fact that the metal is rarely absent from the serpentines, steatites, diallages, and actinolites of the Quebec group. Nevertheless, one other possible source of nickel must be noticed. Roth,† in speaking of the genthite from the chrome mines of Pennsylvania, attributes it to the alteration of nickeliferous chromite; and the almost universal association of the latter mineral with genthite, renders the view deserving of attention. But it must be remembered that chromite alters with great difficulty, while olivine decomposes with extreme ease; and morever the genthite from Oregon contained no chromium, although that metal was diligently sought for. Furthermore, Mr. Diller examined some of the chromite from the Riddle mines, and found that although it was penetrated by crevices filled with secondary minerals containing genthite, the chromite itself showed no evidence of alteration.

Concerning the other silicates of nickel, described under the names of pimelite, alipite, conarite, röttisite, refdanskite, etc., little need here be said. Some of them are probably similar in origin to the better known genthite, although the conarite and röttisite, which contain small amounts of sulphur and arsenic, probably came from nickeliferous sulphides. For the other minerals above named there is too little evidence upon record to warrant any serious attempt at discussion.

Laboratory U. S. Geological Survey, March, 1888.

ART. XLIII.—*Note on the Secondary Enlargement of Augites in a Peridotite from Little Deer Isle, Maine;* by GEORGE P. MERRILL.

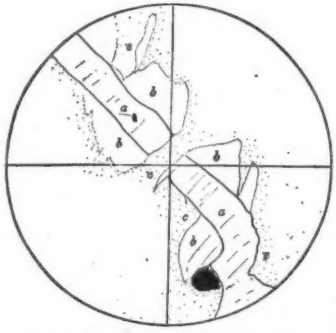
WHILE engaged in the study of sections of a peridotite from Little Deer Isle in Penobscot Bay on the Maine coast, the writer observed certain peculiarities of the augitic constituent which, if rightly interpreted, seem worthy of notice in the columns of this Journal.

The rock consists essentially of olivine and augite, with accessory magnetite, chromite, apatite, and rarely a plagioclase feldspar (?) It therefore belongs to the variety of peridotites which Professor Rosenbusch designates as *picrite*.

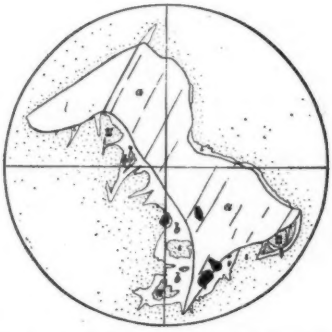
* Report Geol. Survey of Canada, 1863, p. 506.
† Allgem. und Chem. Geologie, vol. i, p. 225, 1879.

Olivine is the prevailing constituent and in nearly every case examined has gone over completely into serpentine. The augite, which is the only constituent to which particular attention need here be called, is of the normal type, of a faint yellow or wine red color in the thin section, and gives maximum extinction angles on clinopinacoidal sections of 40°. The mineral occurs in the form of broad plates with deep, rounded embayments and in long armlike forms reaching out and enfolding the altered olivines, the peculiar habit of the mineral in acting as a binding constituent being here displayed in its best development. On casual inspection by ordinary light the mineral presents no features other than of the ordinary type, the rounded forms of the altered olivine abutting closely against the fresh augite, while the line of separation is perfectly sharp and distinct as I have attempted to show in figs. 1 and 2. Here the portions marked (*a*) and bounded

1.



2.



by the heavy wavy line represent in each figure a single augite individual.* More careful inspection, however, shows that in nearly every instance the augite is surrounded more or less completely by a narrow and extremely irregular colorless border which projects in the form of sharp teeth or tonguelike prolongations for a considerable distance into the serpentine (olivine) granules. This is shown by the portions marked (*b*) in the figures and is very noticeable when the section is viewed between crossed nicols. This irregular border I am inclined to consider as a true secondary growth, formed since the consolidation of the rock and analogous to the hornblendic, feldspathic and quartzose enlargements described by F. Becke,† Irving‡ and Van Hise.§

* In fig. 1 the rock has been fractured and re-cemented by serpentine. The portions in the upper left and lower right field forming originally one crystal.

† Min. u. Petr. Mittheil., vol. v, 1883. ‡ Bull. U. S. Geol. Survey, No. 8, 1884.

§ This Journal, May, 1887.

I am led to these conclusions from a consideration of the following facts: (1.) It would seem very improbable that the augite first separated from the molten magma in such irregular forms; (2.) The original outline of the augite is perfectly sharp and smooth, eminently characteristic of augitic outlines in this class of rocks; (3.) The new portion is much the lighter in color being in fact so nearly colorless as at first to be wholly overlooked when examining the section by ordinary light; (4.) It projects in very irregular and jagged forms into the serpentinized olivine (*c* in the figures). Indeed its appearance is such as to suggest that not only was its formation subsequent to the consolidation of the rock, but that it is an accompaniment of the alteration, the sharp tooth-like edges projecting into the olivines along the curvilinear lines of fracture much like the ordinary beginnings of serpentinization. The new growth, it should be stated, possesses in all cases the same crystallographic orientation as the original, the entire mass extinguishing simultaneously between crossed nicols when in the position indicated in the figures. The new portion is therefore not a secondary hornblende such as Mr. Van Hise has shown occurring as a secondary growth on the augites of certain Wisconsin diabases.

The figures given were drawn with the aid of a camera lucida and show correctly the relative width of the borders and the primary augites in two rather pronounced cases. No attempt has been made to draw in the serpentine portions of the slide, the mineral being merely indicated by the dotted areas (*c*) in the figures. The black opaque spots, it is scarcely necessary to say, represent magnetite.

The writer wishes here to acknowledge his indebtedness to Dr. G. H. Williams, under whose instruction this and other rocks soon to be described were studied during the winter of 1887–88 in the laboratories of the Johns Hopkins University.

National Museum, Washington, Feb. 15, 1888.

ART. XLIV.—*On a New Meteorite from the San Emigdio Range, San Bernardino County, California;* by GEORGE P. MERRILL.

THE fragments of the meteorite briefly described below were given the writer in March, 1887, by Mr. Thomas Price, the well-known Assayer and Bullion Melter of San Francisco, California. The stone was stated by Mr. Price to have been found by a prospector in the San Emigdio Mts., and to have been sent him for assaying, it being mistaken for an ore of

one of the precious metals. Unfortunately, before its true nature was discovered the entire sample received was put through a crusher and hence pieces larger than of a few grains weight are unobtainable.

To the unaided eye the stone is of a dull reddish brown color and shows an irregular fracture, presenting on casual examination nothing indicative of its meteoric origin. A polished surface however, at once reveals its true nature.

The stone belongs to the chondritic variety of meteorites and in thin sections under the microscope is seen to be composed of olivine and enstatite chondri rarely more than one or two millimeters in diameter, imbedded in a base the structural features of which are greatly obscured by stains of iron oxide. It is apparently composed of the same substances as the chondri themselves, but in a fragmental and finely divided condition. The chondri are often of irregular and angular form and show every indication of being themselves *fragments* of some pre-existing meteorite rather than mere products of rapid crystallization. Nickeliferous iron constitutes 6·21 per cent by weight of the stone and occurs in the forms of lumps and irregularly outlined areas often partially surrounding the chondri and acting to some extent as a binding constituent. It is closely associated with pyrrhotite. There is also present in very minute crystals a colorless, polysynthetically twinned mineral which is presumably a monoclinic pyroxene. The minuteness of the crystals and their imperfect outlines renders a satisfactory determination impossible.

An analysis of the stone by Mr. J. E. Whitfield of the U. S. Geological Survey yielded results as follows:

Metallic portion	6·21 per cent.
Soluble in dilute HCl	51·26
Insoluble "	42·23

The metallic portion yielded iron 88·25 per cent; nickel 11·27 per cent; cobalt 0·48 per cent. The portion soluble in HCl includes the olivine, iron oxides and pyrrhotite; the insoluble portion includes the enstatite and twinned pyroxene. The great amount of oxidation which the metallic portion has undergone renders both chemical and microscopic examinations far from satisfactory. Nevertheless as the stone presents very interesting structural features it has been my intention to describe it in detail as soon as proper drawings could be prepared for illustration. In view of the fact that the paper has already been delayed several months it is deemed best to devote a little space to the subject here. I hope to give a more complete description in the near future.

National Museum, Washington, Feb. 15, 1888.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Relative Size of Molecules.*—An attempt has been made by Jäger to determine the relative diameters of some of the elementary molecules and of certain atomic groups, based upon Kohlrausch's investigations on the electric conductivity of certain metallic hydrates and salts in aqueous solution. If in a cylinder of unit length and unit cross section of such a solution there are m molecules; then, the electromotive force along the axis being unity, we may represent by V the velocity with which the kathion will be propelled in the one direction, and by U the velocity of the anion in the other. If ε represent the quantity of positive or negative electricity belonging to each molecule the coefficient of conductivity $\varkappa$ will equal $(u+v)m$, in which $\varepsilon U=u$ and $\varepsilon V=v$; and the specific molecular conductivity λ will be equal to $u+v$. But, according to Hittorf, $\frac{v}{u+v}=n$, in which n is the number of molecules passing through unit space in unit time. Hence $u=(1-n)\lambda$ and $v=n\lambda$. Since the molecules of the ions have a certain velocity, they must meet in unit time a certain number of molecules of a different kind moving in the opposite direction; and therefore they will require energy to overcome the resistance, proportional to their rate of passage. Assuming the molecules to be spheres, and assuming the solution so dilute that no interaction takes place between the molecules of the dissolved substance; then, if the number of molecules in unit volume is α, and if a molecule of radius r passes in a certain direction through an environment of molecules whose radius is ρ, we have $r+\rho=\mathrm{R}$, by resolving the forces in two directions. The result is the same if the radius of the moving molecule is R and the molecules of the environment are mathematical points. If for one given molecule we have $v=\frac{\mathrm{C}}{\mathrm{R}^2}=\frac{\mathrm{C}}{(r+\rho)^2}$ in which C is a constant of integration; while for another molecule $v'=\frac{\mathrm{C}}{(r'+\rho)^2}$; then, dividing the first formula by the second, we have $\frac{v}{v'}=\frac{(r'+\rho)^2}{(r+\rho)^2}$ from which $r=(r'+\rho)\sqrt{\frac{v'}{v}}-\rho$. Substituting in this equation the values for the relative velocities determined by Kohlrausch, and using to find r' and ρ, the diameters of the molecules of water and chlorine as calculated by O. Meyer; i. e. for water 96×10^{-9} and for chlorine 44×10^{-9} centimeters, the value of U for water being 49, Jäger has obtained the formula for calculating the diameter of a given molecule $d=\sqrt{\frac{960400}{v}}-44$, the values obtained being ex-

pressed in 10^{-9} centimeters. The following are the results obtained.

H	$\frac{1}{2}H_2$	I	Br	(CN)	Cl	K	(NH_4)	(NO_3)	(ClO_3)	$\frac{1}{2}K_2$	$\frac{1}{2}(SO_4)$	Ag
15	32	91	91	95	96	97	99	100	111	111	111	111

$\frac{1}{2}(NH_4)_2$	$\frac{1}{2}(CO_3)$	$\frac{1}{2}Ag_2$	Na	F	$\frac{1}{2}Ba$	$\frac{1}{2}Cu$	$\frac{1}{2}Sr$	$\frac{1}{2}Ca$	$\frac{1}{2}Mg$	$(C_2H_3O_2)$
117	119	129	132	135	138	138	141	148	160	160

$\frac{1}{2}Na_2$	$\frac{1}{2}(SO_4)$	Li	$\frac{1}{2}Zn$	$\frac{1}{2}Mg$	$\frac{1}{2}Zn$	$\frac{1}{2}Cu$	$\frac{1}{2}Li$
165	165*	170	175	218*	239*	239*	251*

The values marked with a star were obtained from the electric conductivity of magnesium, copper, and zinc sulphates. It will be noted that not only do the linear dimensions of molecules vary very widely, but that the diameter of a double molecule is greater than twice that of a single molecule; a necessary result of uniting two equal spheres. Moreover, the values for allied elements are nearly the same; as in the group chlorine, iodine and bromine; or barium, strontium and calcium. Again if the number of molecules in unit volume is proportional to the molecular volume, then by multiplying this volume by the molecular weight, we should obtain values proportional to the densities of the elements concerned. Since this relation does not hold good, except for closely allied elements, it follows that the ultimate particles of different molecules are differently arranged.—*Monatsheft,* viii, 498–507; *J. Chem. Soc.*, liv, *Abstr.* 217, March, 1888. G. F. B.

2. *On the Chemical Decomposition produced by Pressure.*—The researches of Spring have shown that many substances which exert no action upon each other at atmospheric pressure, may be made to combine more or less completely if subjected to a pressure sufficient to cause a perceptible condensation. Since the substances experimented with had a smaller volume after union than that of their constituents, it became an interesting question to ascertain whether, in the case of a substance whose volume is greater than that of its constituents, the temperature of conversion can be lowered by pressure. Spring and van't Hoff have examined this action by submitting finely pulverized copper-calcium acetate to a pressure of 6000 atmospheres at a temperature of 16°. The powder, though reduced to a crystalline mass resembling marble, showed no sign of decomposition. It was then subjected to the action of a screw press at a temperature of 40°. The results were marked, three-quarters of the mass being liquefied, and becoming solid again when the pressure was removed. The sides of the containing vessel were covered with a coating of copper and small leaves of copper could be picked out of the mass. The dark blue of the acetate had changed to green, interspersed with white points indicating the separation into copper acetate and calcium acetate. Since the thermic effect of the compression was less than corresponds to a rise of 1°, the above result must have been due entirely to a change of volume. At

50° the piston sank through the mass without resistance. On repeating the first experiment using a lever press, the piston sank 1·25^{mm} in an hour; a rate which would require 110 hours to decompose the entire mass. Under the same conditions, potassium sulphate gave no perceptible diminution of volume. Since the chemical change is a function of the time, the acetate being decomposed more rapidly the higher the temperature and pressure, it is evident that the molecules of a substance do not assume the arrangement which corresponds to the given volume the moment it is reached. Moreover, a substance can be compressed without altering its state if the pressure does not last too long.—*Zeitschr. Physikal. Chem.*, i, 227–230; *J. Chem. Soc.*, liv, Abstr. 341, April, 1888. G. F. B.

3. *On the Vapor-density of Ferric Chloride.*—GRUNEWALD and VICTOR MEYER have made a series of careful determinations of the vapor-density of ferric chloride at various temperatures, with a view of fixing its molecular formula. The chloride was prepared by passing dry chlorine gas over fine iron wire, and after sublimation, appeared as hexagonal plates, of a cantharides-green color by reflected, and purplish red by transmitted light. For the vapor-density in sulphur-vapor, 448°, the apparatus of Victor Meyer was used, filled with nitrogen, the bulb of which was only 45^{mm} in diameter and 125^{mm} long, while the whole apparatus was 670^{mm} long. The boiling sulphur was contained in an iron tube 60^{mm} in diameter, and 620^{mm} long, heated in an air bath by six Bunsen burners. As a mean of four accordant experiments, the vapor-density at 448° was found to be 10·487. The chloride after the experiments was carefully tested and found to contain no trace of ferrous chloride. It therefore appears that even at the temperature of boiling sulphur, the density of ferric chloride is lower than 11·2, the value required by the formula Fe_2Cl_6. The determinations were then repeated in the vapor of boiling phosphorus pentasulphide, 518°, in that of stannous chloride 606°, and in Perrot's furnace at about 750°, 1050° and 1300°. The mean vapor densities of ferric chloride at these temperatures were found to be 9·569 at 518°, 8·383 at 606°, 5·459 and 750°, 5·307 at 1077°, and 5·135 at 1320°. It was found however that a progressive decomposition took place at these temperatures, about a tenth of the chloride being decomposed at 518°, an eighth at 606° and a third at 750° and above. The authors conclude that since at 448° the vapor density of ferric chloride is less than corresponds to the formula Fe_2Cl_6, and since experiments at lower temperatures are not feasible, it follows that no temperature exists at which ferric chloride has a density corresponding to Fe_2Cl_6; and consequently since the vapor-density is lower, it must correspond to the formula $FeCl_3$. In order if possible to check the dissociation of ferric chloride into ferrous chloride and chlorine, the experiments were repeated in an atmosphere of chlorine; the vapor-densities obtained, however, were nearly the same as those obtained in nitrogen. These results agree with those obtained for

aluminum chloride by Nilson and Pettersson, which led them to give to this substance the formula $AlCl_3$.—*Ber. Berl. Chem. Ges.*, xxi, 687–701, March, 1888. G. F. B.

4. *Application of interference fringes to Spectrum Analysis.*—HERMANN EBERT, working in the same direction as Professor Michelson, shows that the method of interference can be used to measure wave-lengths and to detect slight changes in refrangibility of spectral lines. In the latter respect he believes that the method is far more delicate than the ordinary spectrometric methods. One can measure displacements of fringes amounting to $\frac{1}{10}$ of the breadth of the fringes, or $\frac{1}{800}$ of the distance of the components of the sodium line, or a change in the velocity of light of $\frac{3}{8}$ of a kilometer.—*Ann. der Physik und Chemie*, pp. 39–90, No. 5, 1888. J. T.

5. *Penetration of light beneath the surface of water.*—In continuation of his work upon this subject, M. F. A. FOREL finds that, for chloride of silver, the limits of absolute darkness range from 45 meters in July to 110 in March. The variations in these limits correspond closely with those for visibility. The water of Lake Geneva, in which these experiments were tried, is more limpid in winter than in summer.—*Comptes Rendus*, April 3, p. 1004. J. T.

6. *Velocity of Sound.*—MM. J. VIOLLE and TH. VAUTIER conclude from their researches that the velocity of a sound wave diminishes with its intensity; and that the pitch of the sound has no influence on the velocity of the wave.—*Comptes Rendus*, April 3, p. 1003. J. T.

7. *Magnetism and diamagnetism of gases.*—At a meeting of the Physical Society held in Berlin, March 16, Helmholtz described a method of measurement due to Professor Töpler, of Dresden. An index drop of petroleum is placed in a glass tube bent at a very obtuse angle; on one side of the index is the gas which is to be investigated, and on the other side is atmospheric air. When placed between the poles of a powerful electro-magnet, the index is moved according as the gas is more or less strongly attracted than the air; the amount of displacement is measured by a microscope. The delicacy of the method is extremely great. It was observed that oxygen is most magnetic, then come air and nitric oxide; nitrogen, hydrogen, carbonic oxide, carbonic acid gas and nitrous oxide, on the other hand, are diamagnetic. The method can also be employed for the determination of the pressure of small columns of gases.—*Nature*, April 12, 1888. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Three Cruises of the United States Coast and Geodetic Survey Steamer Blake in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic Coast of the United States;* by ALEXANDER AGASSIZ. In two volumes of 314 and 220 pages 8vo, with numerous maps, plates and figures in the text. Boston

and New York, 1888. (Houghton, Mifflin & Co.) Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge, Mass.—These volumes by Prof. Alexander Agassiz contain the best general review of the deep-sea conditions and pelagic and deep-sea life which has been published; and, at the same time, they give a detailed physical and biological account of one of the most interesting regions for deep-sea study in the world, with illustrations of the best kind in profusion.

The three cruises of the Blake occurred in the seasons of 1877–78 from December to March, 1878–79 commencing in November, and in 1880 commencing late in June. The first expedition was under the command of Lieut. Commander C. D. Sigsbee, U. S. N., and the second and third under Commander J. R. Bartlett, U. S. N. The methods of sounding and dredging were gradually perfected with the progress of the work; Mr. Agassiz remarking, in his introductory chapter, that the criticisms of the first equipment and the suggestions of the Commanders and of the Lieutenants and other officers of the ship, constantly modified the methods of work and so changed the apparatus that "it would have been difficult to recognize the original dredging implements as first devised." The character of the final equipment of the "Blake" is the subject of the first chapter, which, like the others, has its many detailed illustrations.

The various lines of sounding and dredging covered, as shown on a large map, the region about the Windward and other West India Islands, the northern half of the Caribbean Sea, a portion of the Gulf of Mexico, and along the Atlantic Coast. Besides these explorations of the American side of the ocean, there is also the work, as the Historical Sketch states, of the Fish Commission under the direction of Prof. Baird, which began in 1871 with naval tugs, but was carried on in 1882 with the steamer "Fish Hawk" and in 1883 and since with the "Albatross," and the still earlier dredging by Pourtalès, an assistant of the Coast Survey, in the years 1867, 1868. "To the memory of L. F. Pourtalès, a pioneer in deep-sea dredging," Agassiz has dedicated his work. Further, the important deep-sea explorations of the Challenger in these waters took place in 1873.

Among the topics treated in the volumes, there are the following: The Florida coral reefs, and connected with it, the subject of the origin of the reefs; the topography of the eastern submarine coast region of the North American Continent and the causes determining the existing features illustrated by several bathymetric maps; the relations of the American and West Indian fauna and flora, embracing the west-American or Pacific as well as east-American, and including the subject of changes in the course of the Gulf Stream, and the geological consequences; the permanence of continents and oceanic basins, a doctrine fully sustained by the facts gathered; the deep-sea or sea-bottom formations; the deep-sea fauna, and in connection the deep-sea rocks and fauna of ancient or geological time; the pelagic fauna and flora,

or that of the open sea not of great depths; the temperatures of the Caribbean Sea, Gulf of Mexico and western Atlantic, illustrated by deep-sea sections of the ocean, and a colored map of the bottom temperature-areas of both the North and South Atlantic; the Gulf Stream; submarine deposits; the physiology of the deep-sea life including the subject of the constitution of sea-water, the degree of darkness of the depths, and other topics; and finally, descriptions of the West Indian fauna and sketches of the characteristic deep-sea types through the various subdivisions of the animal kingdom from Vertebrates to Sponges, which occupy the second volume and are illustrated by nearly 500 figures of species—the work in part of various zoologists whose labors are acknowledged in the Introductory Chapters.

The deep-sea soundings made under the direction of the U. S. Coast and Geodetic Survey in the West Indian seas have brought to light some marvellous facts with regard to depths, which Mr. Agassiz has finely illustrated by maps as well as descriptions. The facts were for the most part first announced in 1884 by Mr. Hilgard, the superintendent of the Coast Survey, citations from whose paper are introduced. A fact of special interest is the great and abrupt depth close along the north shore of the West Indian range of islands, "the 2000-fathom line nowhere more than 14 miles from land," and in one place 1976 fathoms "only 2½ miles out, a declivity of 38°; and, in this line, a depression over 4000 fathoms deep within 75 miles of Porto Rico, the deepest sounding giving 4561 fathoms, indicating a mean submarine slope from the Porto Rico coast-line of 1:14. Further, from this deep depression a trough of 2000 fathoms (the soundings 2000 to 2326 fathoms) extends westward by the north shore of San Domingo, between it and the reef islands north, with slopes part of the way on either side of 1: 8½; and this deep trough diminishing probably to 750 fathoms on the ridge between San Domingo and Cuba, commences again on nearly the same course close by the most southern Cuban shore (within 25 miles) by a trough of 3138 and 3180 fathoms, and is continued westward by two other areas of 3428 and 3206 fathoms pointing down to the southwest angle of the west-Caribbean or Cuban Sea north of Honduras. Agassiz's maps, figs. 56 and 57, show these troughs and the view on page 94 of a model of the Gulf made under Mr. Hilgard's direction, exhibit it still more strikingly through the greatly exaggerated vertical scale. Mr. Agassiz suggests one explanation for the origin of the great depths and correlately for mountains on the borders of the ocean on page 132, and another for some of the depressions on page 104.

Another feature in the sea-bottom topography illustrated by the soundings is the absence, between a point just south of Cape Hatteras and the Bahamas of that steep side-slope of the Atlantic basin along the 100-fathom line which prevails north of the Cape. In place of it, there is a very gradual inclination outward to the 600-fathom line and then a dip off to greater depths, mak-

ing thus a plateau 250 to 300 miles wide which is named the "Blake plateau." Southeast of Savannah and east of Jacksonville the area between the 400-fathom and 500-fathom line is 140 miles broad. The origin of this feature is attributed by Mr. Agassiz to the abrading and transporting action of the Gulf Stream. He states that off Charleston the bottom for the whole width of the Gulf Stream was swept clean of mud or ooze and almost so of living species, proving thus the action of the great stream which along that part of the Atlantic border has a velocity between 3 and 4 miles an hour and a width of 50 to 75 miles.

In the account of sea-bottom formations it is stated that the sediment of the great Mississippi River extends into the Gulf not over 100 miles; beyond this there is the usual sea-bottom life.

The volumes are full of facts of interest relating to the material and nature of the bottom, the condition of the waters, the bathymetric and geographical distribution of living species, and all the various topics alluded to above; and they are made attractive to the general as well as scientific reader by their clear and excellent literary style, the maps, and the many illustrations of the life of the dark depths.

2. *Descriptions of new Fossil Fishes;* by J. S. NEWBERRY.—Dr. J. S. Newberry has a description in volume VI of the Transactions of the N. Y. Academy of Sciences of a new species of Titanichthys larger than the *T. Agassizii* described by him in the Geological Magazine in 1883. The *T. Agassizii*—a fish related to Dinichthys—had a cranium 4 feet 8 inches broad at the occiput, and the mandibles were long slender rods, gently bent upward at the anterior extremity, and there excavated in a deep furrow apparently for the reception of some kind of dental organs. The remains of the new species, including several more or less complete specimens, were found by Dr. Wm. Clarke, at Berea, Ohio, and is named *T. Clarkii.* The cranium is broadly triangular in outline and *five feet* or more between the posterior lateral angles. The mandibles are three feet long, the posterior end, spatulate, six inches wide and turned downward; and the anterior end is turned up like a sled-runner, and has a deep furrow, like *T. Agassizii*, but the whole jaw is much heavier and broader. The under side of the body was protected by a triangular plate three feet long and nearly as broad.

In volume VII of the Transactions Dr. Newberry describes a new and large species of *Rhizodus* from the St. Louis limestone at Albion, Illinois, which he has named *Rhizodus anceps;* it is near *R. Hibberti* Ag., of the Carboniferous limestone of Scotland. The specimen is an anterior half of the dentary bone carrying a large number of acute conical striated teeth about half an inch long, with three great laniary teeth, the anterior and most perfect one of which projects two inches above the margin of the jaw; it differs from the corresponding *R. Hibberti* in being more compressed and double-edged. Dr. Newberry speaks of the discovery of *R. Hardingi* Dawson, in the Lower Carboniferous of

Horton Bluff, Nova Scotia, and remarks that the genus is probably confined to this period.

Other fossil species are described in the same volume from the Erie shale of Ohio—the western extension of the Chemung and Portage rocks of New York and Pennsylvania. They include *Cladodus Kepleri* Newb., *Actinophorus Clarkii* Newb., *Dinichthys curtus* Newb., *D. tuberculatus* Newb. *D. curtus* has been found in the Chemung of Pennsylvania.

The Annals of the New York Academy of Sciences for February, 1888 (vol. iv), contains a description and figures by Dr. Newberry of a new and gigantic species of Edestus, *E. giganteus*, from the coal measures of Decatur, Illinois, with a history of the genus and notes on the species. The specimen is shown to be the dorsal spine, of a gigantic Plagiostome. The spine, which was 18 inches or more in length, had the great breadth of 7½ inches including the denticles, and was two inches thick at center; the broad triangular denticles were 3½ inches long with the edges coarsely denticulate. The species was much larger than *E. vorax* of Leidy or *E. Heinrichsii* of Newberry and Worthen, and different also in the form of the teeth. An admirable figure of the specimen accompanies the paper, with also figures of the other American species.

3. *Natural History of New York. Palæontology*, vol. vii, with Supplement to vol. v, part II; by James Hall, State Geologist and Palæontologist, assisted by John M. Clarke. pp. lxiv, 236, 4 to 45 plates, and pp. 42, with 18 plates. Albany, 1888.—This new volume of the Palæontology of New York is devoted principally to the Devonian Crustacea of North America, exclusive of the subclass Ostracoda. The introduction presents a brief historical sketch of the class as limited to American forms; also, a table showing a systematic arrangement of the subclasses, orders, families and genera, followed by a discussion and tabulation of their chronological distribution. It is shown that the richest trilobitic fauna is in the Corniferous limestone, which has afforded 52 species of crustacea, of which 49 are trilobites and 3 are cirripeds. The generic synonymy and a diagnosis of each genus, with outline figures in the text, precede the main descriptive matter of the volume, and will furnish much assistance to the student of this class of fossils, as well as many valuable references and suggestions to the systematic palæontologist.

The descriptions of species are given in a logical and complete manner. There are 127 species and varieties of Devonian crustacea described, which are arranged in 28 genera. The trilobites include 10 genera and 83 species; the Xiphosura 1; the Eurypterida 2 genera and 3 species; the Phyllocarida 8 genera and 26 species; the Decapoda 1 genus and a single species; the Phyllopoda 2 genera and 2 species; and the Cirripedia 4 genera and 11 species.

One of the most interesting of the genera of Trilobites considered in the volume is that of *Dalmanites*. It comprises 25 species and

varieties, which are arranged in six subgeneric groups. The genus in its early development includes species principally of the type of *D. Hausmanni.* Variation takes place mainly in the lobes and furrows of the glabella and in the ornamentation of the margins of the cephalon and pygidium. During the period of the deposition of the Helderberg series the culmination of development was reached, and many deviations from the original simple type were introduced. The ornamental and defensive armature became extravagantly developed, and several species reached a large size. One form, *D. myrmecophorus*, is estimated from a careful restoration based on a large pygidium, to have had a length of 398^{mm} or 16 inches. The genus Lichas exhibits a similar development and variety of form. It includes the largest and most remarkable of Devonian trilobites, the *Lichas* (*Terataspis*) *grandis* Hall, with individuals reaching a length of nearly two feet and bearing numerous spines and tubercles. The majority of the species of trilobites discussed in this volume are found in the Lower Devonian, and all the genera made their appearance in earlier Palæozoic time.

To many students the portion of the volume relating to species not trilobitic will have the greatest interest on account of the rarity and diversity of the material and its relations with existing forms. This non-trilobitic crustacean fauna holds an important place in the middle and upper Devonian, and but three or four of the nineteen genera here noticed, were continued from earlier faunas.

The supplementary matter is in continuation of vol. v, pt. II, published in 1879, and relates to the classes Pteropoda, Annelida and Cephalopoda. A specimen borrowed from the U. S. Geol. Survey, through C. D. Walcott, and referred by him to *Proëtus marginalis* Con. (Walcott, Monogr. U. S. Geol. Surv., vol. viii, Pal, Eureka Dist., p. 210, 1884), is redescribed as *Proëtus Nevadæ* Hall. This method of treating borrowed type specimens will not meet with general approval. C. E. BEECHER.

4. *Geology of Minnesota, Bulletin No.* 2, 1887. *Preliminary description of the peridotytes, gabbros, diabases and andesytes of Minnesota;* by M. E. WADSWORTH. 160 pp. 8vo, with 12 colored plates of rock-sections.—This Report discusses critically the characteristics of the many rocks studied, their interior changes and other points of petrological interest. It is preliminary to a final report on the Minnesota rocks.

5. *Building-Stone in the State of New York;* by J. C. SMOCK.—Bulletin of the New York State Museum of Natural History, No. 3, March, 1888. Albany, 1888.

6. *Carboniferous Trilobites.*—Lieut. A. W. Vogdes has a paper on American Carboniferous trilobites in the Annals of the N. Y. Acad. Sci., Febr., 1888, reviewing the synonymy and the character of the species, adding notes, and giving figures of 19 species.

7. *Les Dislocations de l'écorce terrestre: Essai de Définition et de Nomenclature par* EMM. DE MARGARIE, á Paris, et Dr. ALBERT

HEIM, á Zurich, 154, pp. 8vo. Zürich, 1888.—This memoir is a thorough systematic descriptive review of the various kinds of faults or displacements, flexures and folds, in rocks, with definitions of the terms used by writers on the subjects, and is both in the French and German languages. Its illustrations are numerous, and illustrate well all the various conditions of rocks described, and its references to authorities are very full. It is therefore an excellent aid to the geological student.

8. *Index der Krystallformen der Mineralien*, Band II, Hft. 1, 2, 3; Bd. III, Hft. 1.

Ueber Projection und graphische Krystallberechnung. 97 pp.

Ueber krystallographische Demonstration mit Hilfe von Korkmodellen mit farbigen Nadelstiften, with 6 colored plates. von VICTOR GOLDSCHMIDT. Berlin, (Julius Springer.)—Something more than a year has passed since the completion of the first volume of Goldschmidt's Index (see this Journal, xxxi, 475, xxxii, 485.) The work which the author has undertaken is a formidable one involving a heavy amount of labor for him, and yet benefitting greatly all workers in this line; it is to be hoped that he may before long be able to bring it to a successful completion. The numbers now issued (in separate parts for the convenience of those using the work) cover all mineral species in F, G, H, with also quartz (vol. III, No. 1), and the execution is of the same excellence as in the earlier parts. The scheme of notation with the methods of projection and calculation which the author has developed with such exhaustive completeness in the Introduction to vol. I of the Index are further elucidated in the accompanying memoirs. The reader who masters them fully will be better able to appreciate the advantages of the author's method. An ingenious device is adopted for the purpose of demonstration by the use of cork blocks with needles bearing colored heads to show the symmetry of the different systems and the relation of the forms belonging to them.

III. BOTANY AND ZOOLOGY.

1. *Flora of the Hawaiian Islands;* by WILLIAM HILLEBRAND, M.D. Annotated and published after the author's death, by W. F. Hillebrand [New York, B. Westermann & Co. 8vo, p. 673, with 4 maps of the Islands.]

Dr. Hillebrand resided for twenty years in Honolulu, engaged in the successful practice of an exacting profession, finding recreation in an exhaustive study of the vegetation of the Sandwich Islands. The plants were examined by him not only in their native haunts but also after they had been transferred to his garden, where they could be investigated under the most favorable conditions. In this way he accumulated the materials for his Flora. These materials were carefully elaborated during his examinations of the leading Herbaria, and the work was ready for the printers early in the summer of 1886.

Dr. Hillebrand's death occurred shortly after the first proofs had been received and corrected, so that the task devolved upon his family of presenting to the world this Flora as a memorial. The task was one of considerable difficulty, inasmuch as certain portions of the treatise had been left in a form which appeared to demand modification. The work has, however, been most skillfully done, and reflects credit on the judgment, learning and good taste of those to whom it was entrusted. In the face of serious difficulties the undertaking has been carried through to a successful completion.

The descriptive part comprises the flowering plants and the vascular cryptogams; 884 species of the former, distributed through 335 genera, and 155 species of vascular cryptogams, in 30 genera. It is thought that 115 species of the above enumerations have been introduced since the discovery of the islands by Cook in 1779. Concerning the geographical relations of the islands and their general features, the lamented author has given a clear and concise account, and he has added some comparisons of the vegetation with that of other countries. The most striking point is the number of varieties in all the leading genera. The occurrence of these varieties is a source of embarrassment to the systematist, but it affords abundant material for the biologist who seeks to determine the range of variation in recent times. The attempt to discriminate between the species connected thus by innumerable intermediate forms has resulted in giving us a work which is unique. The author says: "the descriptions will be found to suffer from want of brevity, of terseness, which the student is inclined to expect in a work of this kind. As an apology I can only plead that my constant endeavor has been to be faithful to nature, that I have thought necessary in order to bring out the general transitions from one form to another to enter upon characters which often are considered of small importance." But no apology is needed. The descriptions though not brief are not prolix. Moreover, in the case of larger genera, analytical keys with emphasis on the more obvious characters, make the treatise an easy one to use.

To the volume is prefixed the sketch of Botany which was employed by Mr. Bentham in his British and Colonial Floras.

From the author's notes, which though somewhat fragmentary, have been wisely added with little if any change, we take the following statements: "Nature here luxuriates in formative energy. Is it because the islands offer a great range of conditions of life? Or is it because the leading genera are in their age of manhood, of greatest vigor? Or is it because the number of types which here come into play is limited, and therefore the area offered to their development comparatively great and varied?"

Such suggestive questions as these are scattered throughout Dr. Hillebrand's preliminary paper; similar enquiries arise when one examines almost any page of this work, which is his monument.

G. L. G.

2. *Recent Advances in Vegetable Histology.*—Whether a new classification of the tissues can be properly regarded as an advance, may be open to question, but the following, applied to the secondary structure of wood, appears to have some advantages for comparative histology. It appears in a study of certain orders by Hitzemann, given in abstract in Bot. Centralbl. 1887, vol. xxxi, p. 91.

A. Elements containing starch. (Parenchymatous system.)

I. Parenchyma arranged radially. (Medullary rays.)

1. Cells chiefly perpendicular to the axis of the stem, generally forming plates of more than one layer of cells.

2. Cells parallel to the axis, almost always forming plates of a single layer of cells.

II. Parenchyma arranged tangentially, connecting the medullary rays.

3. Short cells, generally in groups of more than one row. Wood-parenchyma.

4. Elongated cells, in a plate of a single layer. Substitution fibers and fibrous cells, forming a transition to the next group.

B. Elements containing no starch.

I. Fiber-system. (Mechanical system.) Area of cross-section of the element is but a small fraction of that of a longitudinal section.

5. Pits not present, or very minute, or larger with no distinct border. Libriform-fibers.

6. Pits present and provided with a large border; no difference in size or structure between the bordered pits on the side and end walls. Tracheïd-fibers.

II. Trachael system. System for conducting water.

7. Pits of the side and end-walls show no marked difference in structure, but a great difference in size. Tracheïds.

8. Pits exhibit noticeable differences in structure, complete perforation of the partition. Ducts.

It will be observed that this classification is open to the objection which lies against every system thus far proposed, namely: that both morphological and physiological considerations enter into its construction. But for comparative studies like that undertaken by Hitzemann, the classification seems simple and may prove useful.

Berggren (in 1883) studied the economy of the spirally-thickened cells in the roots of some Taxineæ. In the leaves of certain species of Sansevieria, Areschoug (Bot. Centralbl. xxxi, 258) finds similar cells with extraordinary thickness, apparently serving as constituents of a true "water-tissue," instead of being, as in many other well-known cases, unequivocal tracheids.

Prael (Ber. Deutsch. Bot. Ges. 1887, 417) has lately investigated the structure of the wood which forms during the repair of young twigs and stems which have been injured. It has long been known that this new wood partakes somewhat of the nature of heart-wood rather than of sap-wood. The results of Prael's

work may be interpreted as showing that the protective wood which grows over wounds always exhibits a notable agreement in all particulars with the heart-wood of the same plant, even sharing its tyloses, resins, gums, and to a certain extent its coloring matters.

The vascular bundles which are termed "concentric" are of two kinds: (1) the xylem is surrrounded by the phloem, (2) the phloem is surrounded by the xylem. The first is characteristic of ferns, although examples are not wanting among flowering plants. Both of these kinds have been examined by Möbius (Ber. Deutsch. Bot. Ges. 1887, 2), who adds to the results of his special investigation a convenient synoptical table of the orders in which these different types are to be seen.

von Tavel (Ber. Deutsch. Bot. Ges. 1887, 438) gives an interesting account of his investigation of the mechanical structure of bulbs. Bulbs are, in general, reservoirs of food which grow under a certain amount of pressure from surrounding soil. In some cases the weight of superincumbent earth is very considerable. Under these restricting pressures the bulb would become much distorted were it not protected by strong mechanical elements. A study of the distribution of these elements and an examination of the epidermal structures of bulbs show that they have no relation whatever to the systematic place of the species, but that they are strictly adaptive.

The comparative histology of allied orders of flowering plants continues to attract a considerable number of investigators, but as yet without any very satisfactory results in the direction of generalization. Nor can it be expected that the survey of the limited fields thus far brought under observation can reveal any general laws, but the value of the results of such scattered and often very fragmentary histological studies cannot well be overestimated. Among those most recently published are the following: Hitzemann's examination of Ternstroemiaceæ, Dipterocarpeæ, and Chlænaceæ, and Saupe's investigation [Flora, 1887, p. 259] of the wood of the Leguminosæ. The conclusions reached by the latter may be briefly stated thus: (1.) It is impossible to separate the suborders Papilionaceæ Cæsalpiniaceæ, and Mimoseæ on the basis of wood-structure. But, on the other hand, it is perfectly practicable to distinguish in these suborders, closely related and sharply marked groups of small sizes. And, moreover, it is easy to detect, in some instances, a close anatomical resemblance between two members of some of these groups, even when they grow naturally under wholly diverse circumstances. But their species cannot as yet be distinguished clearly by means of the histological character of the wood. G. L. G.

3. *Forms of Animal Life.*—A Manual of Comparative Anatomy, with descriptions of selected types, by the late G. Rolleston, Linacre Prof. Anat. Phys., Oxford; second edition, revised and enlarged by W. H. Jackson, F.L.S., Nat. Sci. Lecturer, St. John's College. 938 pp., 8vo. Oxford: 1888. (Clarendon

Press.)—This large volume is a very full Manual of Comparative Anatomy for the student, and is well adapted to its purpose by the completeness of its explanations and directions and the number of prepared types which it discusses. These embrace species from all the grander divisions of the Animal Kingdom, in the following order: Mammals, Birds, Reptiles, Amphibians, Fishes, Ascidians, Gastropods, Lamellibranchs, Insects, Crustaceans, Asteroids, Chætopods, Hirudinea, Cestoda, Polyzoa, Anthozoa, Hydrozoa, Porifera, Infusoria and Amœbina. The subjects are illustrated by 14 excellent plates of the various subjects considered, besides various fine wood cuts.

4. *Die Japanische Seeigel von Dr. Ludwig Döderlein*, of Strassburg. 1 Theil. Fam. Cidaridæ und Saleniidæ, mit Taf. I–XI. Stuttgart, 1887 (E. Schweizerbart'sche Verlagshandlung). —This memoir has remarkably beautiful plates illustrating descriptions of some new species of Cidarids from Japan and also recent species of other regions described by different authors, and also gives a review in detail of the general character and history of the group.

5. *Bibliotheca Zoologica* II. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten vom Jahre 1861–1880, selbständig erscheinen sind mit Einschluss der allgemein-naturgeschichtlichen periodischen und palæontologischen Schriften, bearbeitet von Dr. O. Taschenberg, Docent an der Univ. Halle. Fünfte Lieferung, Signatur 161–200. Leipzig, 1888. (Wm. Engelmann). The earlier parts of this important work have been noticed in volumes xxxiii and xxxiv of this Journal.

IV. Miscellaneous Scientific Intelligence.

1. *The Constant of Aberration.*—Professor Hall has published in the Astronomical Journal the results of his reduction of the observations made in the years 1862–7 upon α Lyrae by Professors Hubbard, Newcomb, Harkness and himself with the prime vertical transit instrument of the Naval Observatory, for the purpose of determining the constants of mutation and aberration. He obtains as the most probable value of the constant of aberration $20''{\cdot}4542 \pm 0''{\cdot}0144$. This with Michelson and Newcomb's velocity of light gives for the solar parallax $8''{\cdot}810 \pm 0''{\cdot}0062$.

2. *Discovery of Small Planets.*—The small planet (183) Istria was rediscovered by Paliser April 7th. Of the first 250 of the planets at least 238 have therefore now been observed at a second opposition. Only two of the exceptions are between (200) and (250). The planet (278) was discovered by Borelly at Marseilles, unless this should prove to be Xantippe (156).

3. *Michigan Mining School.*—This mining school, at Houghton, Michigan, is the only school of mining east of the Mississippi that is located in a region of mines. Being on Keweenaw Point, in the vicinity of the great copper mines, it has the special ad-

vantages necessary to successful instruction. The faculty include Dr. M. E. WADSWORTH, Director and Professor of mineralogy, petrography and geology; R. L. PACKARD, A.M., Professor of chemistry, and R. M. EDWARDS, E.M., Professor of mining and engineering. Dr. Wadsworth has recently been made State Geologist of Michigan.

Die Regen-Verhältnisse des Russischen Reiches, von H. Wild, mit seriem atlas; Supplement band zum Repertorium für Meteorologie, herausg. Kais. Acad. Wiss. St. Petersburg, 1887.

Nomenclator Floræ Danicæ, Auctore Joh. Lange, 354 pp. 4to, Leipsic, 1887 (F. A. Brockhaus).

The International Scientist's Directory of 1888, compiled and published by S. L. Casino, Boston, and just issued, contains complete lists of the geologists of Europe with their addresses, and also of other men of science. It is a very convenient volume for students in all departments of science.

The Manual Training School, comprising a full statement of its aims, methods and results, with figured drawings of shop exercises in woods and metals; by C. M. Woodward, A.B. (Harvard) Ph.D. Boston, 1887 (D. C. Heath & Co.)—Industrial Instruction: a pedagogic and social necessity, together with a Critique upon objections advanced; by R. Seidel, Mollis, Switzerland. Transl. by Margaret K. Smith, State Normal School, Oswego, New York. 160 pp. 12mo. Boston, 1887 (D. C. Heath & Co.)

The above are two valuable works; the first one of great importance to the scholars of a training school or for self-training.

A Treatise on Alcohol with tables of spirit gravities, by Thomas Stevenson, M.D., London. 2d edition. 74 pp. 12mo, London, 1888. (Gurney & Jackson.)

Introductory Text-book of Geology by David Page, LL.D., F.G.S., revised and in great part re-written by C. Lapworth, LL.D., F.G.S., Prof. Geol. and Pysiogr., Mason College, Birmingham, 12th edit., 316 pp., 12mo. Edinburgh and London, 1888. (Wm. Blackwood & Sons.)

OBITUARY.

GERHARD VOM RATH, Professor of Mineralogy at the University of Bonn, died on the 23d of April. He was born August 20, 1830, so that his life is cut off prematurely, and yet through his indefatigable energy and enthusiasm the amount of scientific work which he accomplished was truly remarkable. His inaugural dissertation, on the composition of the scapolites, was published in 1853 (Poggendorff's Annalen, vol. l) and from that time on he was never idle. There are but few important mineral species to our knowledge of which he has not contributed. The most intricate problems in crystallography were those in which he took most pleasure, and to his clear mind the complete twinning laws of the triclinic feldspars, the obscure distorted forms of gold and silver, and a host of similar problems presented no difficulty; and his skillful hand was always equal to the task of representing the forms on paper. A son-in-law of Gustav Rose, he was a worthy follower in his footsteps in the character and scope of his labors. He was a great traveler, especially during the later years of his life, and many are the papers he has written, mostly scientific, but others more popular, giving the results of his observations in Greece, Palestine, Mexico, the western United States, and other regions. Professor vom Rath had a most charmingly genial disposition, and a wide circle of friends, by no means limited to Germany, will mourn his too early death.

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